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The RAYON
INDUSTRY

The RAYON INDUSTRY

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BY

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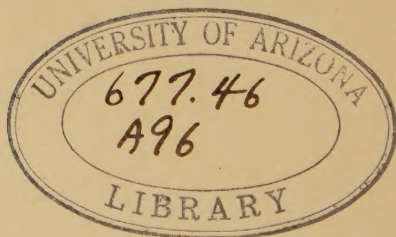
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PREFACE

THE evolution of the Rayon Industry and its rapid growth from crude beginnings in 1880 to its present well-developed state is a distinct result of persistent research. Much, therefore, is due to those individuals and Rayon corporations who stood the pressure of early struggles.

Although Count Hilaire de Chardonnet produced the first commercial yarn of Rayon nearly fifty years ago, his product has come to be recognized as a textile of importance only within recent years. As its development progressed, information both of a theoretical and practical nature was constantly sought, information that was largely and properly withheld as the property of the originators. Hence, even at this advanced stage and notwithstanding the fact that this volume is in its second edition, it is still lacking such data or facts about improved processes as are held secret by the Rayon manufacturers.

This volume has been written with two objects in view: to attempt a comprehensive outline of this new product Rayon, still known on the other Continents as Artificial Silk; and to supply the demand on the part of engineers, textile manufacturers, chemists and bankers for known information and facts. To be sure, Rayon has been widely discussed and several books about it have appeared in Europe, where it originated, but this is practically the first attempt to correlate all the factors of economics, engineering and processing into a single comprehensive volume.

The writing of this book was further prompted by the knowledge that groups of financial interests, unacquainted

with the fact that this is a highly technical industry and unacquainted also with the large-scale financing that is necessary for its proper development, are considering this field for investment. This volume, therefore, aims to point out that success in Rayon production depends upon more than capital and enterprise. A technical staff of the first order and thoroughly versed in the technical intricacies of the industry is, indeed, the first requisite.

The quality of Rayon Yarn has been greatly improved and the notable changes taking place in the industry are making for a steady increase in production. This follows the author's anticipations as printed in the first edition. The day, therefore, is not far distant when the price of Rayon yarn will come into line with that of cotton, the most abundant yarn. With such an alignment of prices, even assuming the somewhat more expensive Rayon and with increasing channels for its use, the demand will greatly increase. Its future cannot be too strongly emphasized.

Because of the immense amount of material that had to be considered, the indulgence of the reader is sought, for any inadvertencies which may have occurred.

The author gratefully acknowledges the help of all authorities. Due acknowledgment will be found for all references throughout the text except where search failed to reveal the source. In such instances apology is due as no such omissions are intentional.

Thanks are extended to those Rayon machinery companies which supplied information in regard to their apparatus. Such machinery is illustrated here to indicate types of construction and not to recommend any particular make of apparatus.

The author is also indebted to the members of the engineering staff of the M. H. Avram Engineering Corporation, to Mr. Alexis Sommaripa, Manager of the Business Research Department of the DuPont Rayon Company, whose prepara-

tion of that part of Chapter VII on "Trade Economics," entitled "Sales of Rayon" and whose outline covering the "Glossary of Rayon fabrics," is given in Chapter XVII on "Processing" and will be found valuable studies of facts; to Professor Chas. B. Mullin, Professor of Textile Chemistry and Dyeing at Clemson College, S. C., who has so carefully edited the chapters on Viscose, Cupra-ammonium and Nitro Processes and supplied valuable material for the Acetate Process.

The author can not close this effort without grateful appreciation to Dr. Marco Biroli, Director-General of La Soie de Chatillon of Italy, who personally guided the author through some of their Rayon plants and the new Acetate plant at Vercelli, Italy; and to M. François Reinemund, President of the Société Générale de Soie Artificielle, from whom the author, while in Antwerp, obtained much valuable information on the Belgian and European Rayon situation; to Dr. Arthur Moth-ruff, President of the American Bemberg Corporation; to Dr. B. M. Balsam, Chairman of the American Chatillon Corporation; to Mr. L. A. Yerkes, President of the DuPont Rayon Company; Mr. Thomas A. Duffey, Vice-President of the Delaware Rayon Company; Mr. H. S. Rivitz, President of the Industrial Rayon Corporation; Mr. S. A. Salvage, President of the Viscose Company; Mr. Bertrand Clarke, Managing Director of the Cellulose Acetate Silk Company, Ltd., of Lancaster, England; Mr. Martin Coles Harman, Chairman of the Branston Artificial Silk Company, Ltd., of Burton-on-Trent, England, as well as Messrs. Carl and Hans Haubold of Chemnitz, Germany; Mr. Henry Chalmers, Chief, Division of Foreign Tariffs and Mr. Edward T. Pickard, Chief, Textile Division, both of the Department of Commerce, Washington, D. C., and to the members of the Gebrüder-Bader organization of Vienna and Mahr-Chroston Czecho-Slovakia, producers and manufacturers of Rayon goods, and others

whose names I may inadvertently have omitted and who have zealously cooperated and responded to my requests for correct information regarding their own sphere of action in the Rayon industry.

MOIS H. AVRAM.

New York, N. Y.,
October, 1929.

CONTENTS

	PAGE
PREFACE	v
CHAPTER	
I. HISTORICAL	1
II. IMPORTANCE AND GROWTH OF THE INDUSTRY	16
Rayon Progress Here and Abroad.—Rayon's Future.	
III. THE PRODUCTION OF RAYON	45
Relative World Production.—Production by Countries.—European Production.—Production in Asia.—Production Possibilities.—Comparative Qualities.	
IV. OTHER PRODUCTS FROM CELLULOSE SOLUTIONS	120
Films.—Celaphane.—Sausage Casings.—Unshatterable Glass—Waterproofing.—Wallpaper Surfacing.—Paints and Lacquers.—Covering for Paper and Metallic Gauze.—Sizing for Fabrics and Threads.—Viscose Rubber.—Viscose Leather.—Insulation Plates.—Hollow Filament Yarn.—Rayon Waste.—Staple Fibre.—Artificial Wool.—Artificial Horsehair.—Artificial Straw.—Artificial Ribbon.—Delustered Rayon.	
V. FINANCIAL	133
VI. CHARACTERISTICS OF RAYON AND THE COMMON TEXTILE FIBRES OF COMMERCE	181
Physical Properties.—Mechanical Characteristics or Properties of Rayon.—Colloidal Solutions.—Commercial Varieties of Cotton.—Sea Island Cotton.—Egyptian Cotton.—South American Cotton.—Indian Cotton.—China Cotton.—Microscopy.—Wool.—Chemical Composition of Raw Wool.—Hygroscopic Quality.—Effect of Moisture on Physical Properties of Wool.—Linen (Flax).—Chemical Character.—Ramie.—Silk.—Physical Divisions of the Silk Industry.—Properties of Silk.—Market Terminology.—Microscopy.	
VII. TRADE ECONOMICS	225
Trade Name.—Sales of Rayon.—International Trade Economics.—Rayon Products and Trade Marks.—Consumption of Various Types of Rayon Yarns.—Consumption of Rayon by Different Industries.—Merchandizing of Rayon.—Summary of Consumption of Rayon.—Advertising.—Tendencies toward Consolidations.—Tariffs.	

CHAPTER	PAGE
VIII. FUNDAMENTAL PRINCIPLES IN RAYON PRODUCTION	319
The Spinning Solutions.—Preparation of the Spinning Solution. —The Spinning Process.—Further Handling and Processing of the Filament.—Apparatus of General Application.—Spinnerets. —Gathering of the Spun Threads.—Washing of Rayon on the Spool.—Drying.—Abbreviated Processes.—Modified Textile Equipment.	
IX. RAYON ENGINEERING PROBLEMS	353
Types and Design of Buildings.—Water Requirements.—Mineral Constituents Found in Natural Waters.—Hardness.—Water Softeners.—Choice of Equipment.—Relation of Water to Process. —Air Conditioning or Temperature and Humidity Regulation. —Power, Steam and Fuel.—Research Laboratories and Develop- ment.—Transportation and Yard Traffic Regulation.—Labor and Labor Living Conditions.—Engineering of Process Details.	
X. PRINCIPAL RAW MATERIALS	414
Cellulose.—Wood Cellulose.—Wood Pulp.—Water.—Cot- ton Flax.—Cornstalks and Straw.—Chemicals.	
XI. VISCOSE PROCESS	436
History.—The Raw Materials.—The Plant Process.—Coagulat- ing or Spinning Bath Preparation.—The Spinning Machine.— The Finishing or Preparation of Yarn for the User.—Final Treat- ment of Reeled Skeins.—Plant Design.—Improvement Ten- dencies.	
XII. CUPRA-AMMONIUM PROCESS	523
Steps in the Process.—Preparation of the Solution.—Spinning.	
XIII. THE NITRO, OR CHARDONNET, PROCESS	544
History.—Steps in the Process.—Preparing the Spinning Solu- tion.—Denitration.—Finishing.—Solvent and Acid Recovery.	
XIV. THE ACETATE PROCESS	559
History.—Chemistry of the Process.—Spinning.	
XV. RECOVERY OF CHEMICALS AND VOLATILE SOLVENTS USED IN THE PRODUCTION OF RAYON	581
Recovery in the Viscose Process.—Sulphuric Acid Absorption Process.—Absorption in Water.—Absorption in Cresol (Bregat Process).—Recovery of Acetic Acid in Cellulose-Acetate Rayon Production.—Solvent Recovery Process Using Solid Absorbents. —Absorption in Silica Gel.	
XVI. REPRESENTATIVE MODERN RAYON MILLS	607

CONTENTS

xi

CHAPTER	PAGE
XVII. PROCESSING	638
Weaving and Knitting.—Glossary of Rayon Fabrics.—Dyeing. —Delustering.	
XVIII. MEASURING AND TESTING RAYON YARNS	716
Standards.—Definitions.—Test Methods.—Strength.—Control Tests for Viscose Process.—Control Tests for Nitro-Cellulose Process.—Control Tests for Cupra-Ammonium and Cellulose- Acetate Process.	
XIX. PATENTS	747
APPENDIX	805
INDEX	881

CHARTS

	PAGE
1. Relative World Production of Raw Silk and Rayon	47
2. Comparison Actual United States Production to Trend Curve	49
3. United States Production, Imports and Consumption of Rayon	50
4. Comparison of United States Production of Rayon to World Production	52
5. Comparative World Production of Textiles	183
6. Classification of Silks	197
7. Trend of Value of Textile Production	235
8. Index of Trend of Value of Textile Production	237
9. Consumption Trend of Cotton, Wool, Silk and Rayon	238
10. Average Yearly Prices of Rayon and Real Silk	242
11. Comparative Wholesale Prices	244
12. Wholesale Price Index	245
13. Prices of Rayon	248
14. Price Trend for 150A Denier Rayon	252
15. Sales Value of Fabrics—Silk Department	260
16. Sales Value of Fabrics—Wash Goods Department	262
17. Relative Value of Sales of Raw Fabrics	263
18. Women's Rayon Underwear	265
19. Women's Knit and Woven Underwear	266
20. Value of Sales of Women's Underwear	269
21. Women's Wear	271
22. Rayon Hosiery Production in United States	273
23. Imports of Rayon Yarn into United States	296
24. Imports of Rayon into United States by Denier	297
25. Consolidations and Group Control of Rayon Companies	310
26. Group Control of Rayon Companies	311
27. Flow Sheet of Four Rayon Processes	351

TABLES

TABLE	PAGE
1. Growth of Rayon Production by Years and Countries	45
2. Companies and Factories in Operation and under Construction	46
3. World Production of Raw Silk and Rayon	48
3A. Comparison World Production of Four Principal Fibres	48
4. United States Consumption, Production and Imports	51
5. United States Production of Rayon by Companies	53
6. Summary of Rayon Plants Producing and Projected in United States	60
7. Brazilian Production	62
8. Italian Production	63
9. Summary of Rayon Plants in Italy	68
10. British Production	70
11. Summary of Rayon Plants in England	77
12. German Production	78
13. Summary of Rayon Plants in Germany	84
14. French Production	87
15. Summary of Rayon Plants in France	97
16. Production in Holland	98
17. Production in Belgium	99
18. Summary of Rayon Plants in Belgium	102
19. Production in Switzerland	103
20. Summary of Rayon Plants in Switzerland	104
21. Production in Austria	105
22. Production in Czecho-Slovakia	105
23. Summary of Rayon Plants in Czecho-Slovakia	107
24. Production in Poland	108
25. Summary of Rayon Plants in Poland	109
26. Production in Spain	110
27. Summary of Rayon Plants in Spain	111
28. Production in Japan	114
29. Summary of Rayon Plants in Japan	117
30. A Prophecy—World's Production	118
31. Company Profits, Dividends and Reserves	140
32. Comparative Statement Industrial Rayon Corporation	150
32A. New York Market Quotations of Rayon Shares	180
33. Refractive Index of Rayon Yarns	185
34. Breaking Strength of Rayon Yarns and Silk	187
35. Comparative Properties of Varieties of Cotton	200
36. Effect of Moisture on Strength and Elasticity of Cotton Yarns	201
37. Effect of Moisture on Strength of Linen Sail Cloth	208
38. Ramie	210
39. Ramie Fibre Analysis	210

TABLE	PAGE
40. Silk Analysis	220
41. Per Capita Consumption of Rayon	239
41A and B. Fibre Consumption in Various Industries for 1927	240
42. Yearly Prices of Japanese Raw Silk and Rayon	241
43. Rayon Price on Denier A Grade	249
44. Domestic Rayon Prices	251
45. Consumption of Rayon by Industries—Pounds	256
46. Consumption of Rayon by Industries—Percentage	257
47. Importance of Consuming Trades	257
48. Trend of Hosiery Production	275
49. Men's Hosiery Production in United States	276
50. Boys', Misses', Infants' and Children's Hosiery Production	276
51. Women's Hosiery Production in United States	277
52. Women's Hosiery Consumption by Classes	280
53. Imports of Rayon into United States by Countries	295
53A. Imports of Rayon into United States 1927 by Denier	298
53B. Imports of Rayon into United States 1928 by Denier	299
54. Production, Imports and Exports of Rayon for Brazil	300
55. Production, Imports and Exports of Rayon for Italy	301
56. Distribution of Exports from Italy	301
57. Production, Imports and Exports of Rayon for England	302
58. Principal British Markets	302
59. Distribution of Great Britain's Rayon Imports	302
60. Production, Imports and Exports of Rayon for Germany	303
61. Production, Imports and Exports of Rayon for France	303
62. Production, Imports and Exports of Rayon for Holland	304
63. Production, Imports and Exports of Rayon for Belgium	304
64. Production, Imports and Exports of Rayon for Switzerland	305
65. Production, Imports and Exports of Rayon for Austria	305
66. Production, Imports and Exports of Rayon for Czecho-Slovakia	305
66A. Production, Imports and Exports of Rayon for Poland	306
67. Production, Imports and Exports of Rayon for Spain	306
68. Production, Imports and Exports of Rayon for Japan	307
69. Production, Imports and Exports of Rayon for Other Countries	308
70. United States Rates of Duty on Rayon Yarns and Artificial Horsehair	313
71. Valuation Investigation Report	314-315
72. United States Rate of Duty on Manufactures of Rayon	316
73. Tariff Rates on Rayon for Nine Foreign Countries	317
74. Analysis of Import Duties of Ten Principal Countries	318
75. Report of Mineral Analysis	366
76. Impurities and Troubles with Water Supplies	368
77. Principles Employed in Removing Impurities	369
78. Comparative Costs of Purified Water	389
79. Cost of Steam Power Using Turbines	403
80. Reductions in Cost of Power	404
81. Cost of Uniform Hydro-Electric Power	404
82. Cost of Variable Hydro-Electric Power	405

TABLE	PAGE
83. Wage Scale	408
84. Hours of Labor	409
85. Analysis of Kinds of Wood	416
86. Rayon Wood-pulp Specifications	430
87. Operation Cycle under Bobbin Spinning Method	483
88. Operation Cycle under Centrifugal-pot Method	496
89. Acid Mixture	547
90. Nitrating Conditions	549
90A. All Rayon Fabrics	669
91. Rayon and Silk	693
92. Rayon and Wool	694
93. Rayon and Cotton	695
94. <u>Use of Rayon Containing Fabrics in Women's Apparel</u>	696
95. Use of Rayon Containing Fabrics in Interior Decoration	697
96. Miscellaneous Rayon Contained Goods	697
97. Number of Turns in Rayon Strength Skeins	729
98. Reactions of Natural Silk and Rayon	731
99. Conversion of Statements of Chemical Composition	805
100. Conversion of Hardness from Degrees to Parts per Million	805
101. Equivalents of Ounces in Decimals of the Pound	808
102. Comparison of Avoirdupois and Metric Weights	811
103. Kilogram Equivalents in Pounds to Four Decimals	812
104. Pounds Weight Equivalents in Kilos and Decimals	813
105. Metric Weight Equivalents in Pounds, Ounces and Grain Avoirdupois	814
106. Metric Weight Equivalents by Multiples of Ten Grams	815
107. Japanese Weights and Measures with English and Metric Equivalents	816
108. Chinese Weights and Measures with English and Metric Equivalents	817
109. Yarn Count Conversion Factors	823
110. Conversion Factors	823
111. Comparative Yarn Tables	825-832
112. Numbering Cotton Yarn and Spun Silk by Weight in Grains of 120 Yards	833
113. Yards of Silk to Pound in Sizes by Deniers	834
114. Diameters of Threads: Cotton, Worsted and Woolen Yarns	835, 836
115. Cotton Regain	838
116. Worsted Regain	839
117. Japan Raw Silk Regain	840
118. Relative Humidity	842-844
119. Conversion of Thermometer Readings	845
120. Analysis of Fibres and Yarns in Fabrics	846
121. Equivalents of Twaddle, Baumé and Specific Gravity Scales	848
122. Artificial Silk Counts	849
123. Artificial Silk Yarns	850
124. Comparative Value in Dollars of One Pound of Silk at Various Rates of Boil-off	853

125.	Yards to Pound of Thrown Silk	854
126.	Increase in Weight	855
127.	Denier Table	856

USEFUL TABLES

	PAGE
English Weights and Measures	806
Metric Equivalents	810
Conversion Factors	818
Yarn Numbering	820
Normal Condition of Textile Materials	837

ILLUSTRATIONS

FIGURE	PAGE
1. Count Hilaire de Chardonnet	4
2. Condensed Flow-sheet of Chardonnet or Nitro Process	13
3. Condensed Flow-sheet of Cupra-ammonium Process	13
4. Condensed Flow-sheet of the Viscose Process	14
5. Condensed Flow-sheet of the Cellulose Acetate Process	14
6. "Garnett" Waste Opener with Three Shifts	128
7. World Production of the Common Textile Fibres	181
8. Cross-section of Viscose Rayon	189
9. Viscose Rayon	189
10. Cross-section of Nitro or Chardonnet Rayon	190
11. Nitrocellulose or Chardonnet Rayon	190
12. Cross-section of Cupra-ammonium Rayon	191
13. Cupra-ammonium, Glanzstoff Rayon	191
14. Cross-section of Acetate Rayon Yarn	192
15. Cotton Fibres—Longitudinal Views	202
16. Cotton Fibres—Cross-section	202
17. Wool Fibres after Removal of Grease	207
18. Wool Fibre Structure Diagram	207
19. Flax Fibre	209
20. Flax Fibres—Cross-section and Longitudinal Views	209
21. Ramie Fibre	211
21A. Ramie Fibre—Cross-section and Longitudinal Views	211
22. Raw Materials. Spruce Logs and Cotton Linters	212
23. Finished Rayon Yarn	213
24. Silk Worms Devouring Mulberry Leaves	215
25. Stages in Growth of Silk Worm	216
26. Feeding Silk Worms	217
27. Silk Worm Cocoons	217
28. Sorting and Grading Cocoons	218
29. Unreeling the Cocoons	219
30. Silk Reeling in Japan	221
31. Spinning Silk from Floss	223
32. Cross-section of Silk Fibre	223
33. Raw Silk under the Microscope	224
34. Skein, Tubes, Cones and Spools	280
35. Specimen of Consumer's Advertisement	287
36. Specimen of Trade Advertisement	290
37. Measurement of Viscosity	322
38. Rayon Spinning Pump	333
39. Rayon Spinning Pump	334

FIGURE	PAGE
40. Spinnerets	338
41. Evolution of the Rayon Spinneret	342
42. Manually Controlled Orifice Feed—Gravity Type	371
43. Manually Controlled Orifice Feed—Pressure Type	373
44. Automatic Stop-and-start Orifice Feed—Gravity Type	374
45. Tipping-meter Feed, Gravity Type	375
46. Proportionating Feed, Closed Pressure Type	376
47. Concrete Settling Basin	378
48. Cylindrical Settling Tank	379
49. Wood Gravity Filter	380
50. Horizontal Steel Pressure Filter	381
51. Vertical Zeolite Softener	385
52. Modern Filtration and Softening Plant	390
53. Woolen Fibres Processed in Unsoftened Water	392
54. Woolen Fibres Processed in Water Free from Hardness	392
55. Air-conditioning Unit—Capacity 5000 Cu. Ft.	398
56. Air-conditioning Unit—Capacity 2500 Cu. Ft.	400
57. Northern Canadian Spruce	418
57A. Barking Plant	420
58. Wood Storage	421
59. Digesters Holding Thirty-six Cords of Wood	423
60. Screening Room	425
60A. Drying Machine for Cutting Sheets to Size	426
61. Wood-cellulose Baled Ready for Shipment	427
62. Plan and Elevation of Kipawa Mills	429
62A. Flow Sheet for Alpha Cellulose Production	435
63. Steeping Hydraulic Press	445
64. Hydraulic-horizontal Combined Steeping Press	446
65. Shredding Machine	448
66. Shredder	449
67. Crumb Aging Cans	449
68. Xanthating Drum Elevation	451
69. Xanthating Drum Plan View	451
70. } Viscose Solution Mixers	453
71. }	
72. }	
73. Aging Tanks	454
74. High-pressure Filter Press	456
75. Bobbin Spinning Machine	461
76. Cross-section Haubold Centrifugal-Pot Spinning Machine	463
77. Borletti Piston Pump—Side View	466
78. Borletti Piston Pump—Longitudinal Section	466
79. Borletti Spinning Pump	467
80. Spinning Pump, Gear Type	468
81. Candle-Filter	469
82. Sectional Elevation of Bakelite Filter	469
83. Spinnerets	470
84. Godet Roller	474

ILLUSTRATIONS

xxi

FIGURE

	PAGE
85. Spinning Funnel	475
86. Motor-driven Spinning Pot or Box	477
87. Centrifugal Viscose Rayon Spinning Machine	479
88. Grid Ozonizer for Electric Air Purification	481
89. Electric Air Purifying Apparatus	482
90. Bobbin Washing Machine	484
91. Bobbin Dryer	486
92. Drying Yarns on Bobbins	487
93. Two-decker Twisting Machine	488
94. Skein Washing, Desulphurising, Bleaching, Souring Machine	490
95. Skein Washing, Desulphurising, Bleaching, Souring Machine	491
96. Hydro Extractor	493
97. Automatic Skein Drying and Conditioning Chamber	494
98. Power Press, Bundling Box and Hand Press	495
99. Reeling Machine	498
100. Reeling Machine—Side Elevation	498
101. Single Reel	499
102. Double Reel	499
103. Single and Double Winding Collapsible Reel	500
104. Washing, Desulphurizing, Bleaching Machine	501
105. Front View, Automatic Skein Washing, Bleaching, and Dyeing Machine	503
106. Side View of Fig. 105	504
107. Stretch Skein Dryer	504
108. Side Elevation of Rotary Kier	526
109. Boiling Kier	528
110. Cupra-ammonia Solution Cylinder Producer	531
111. Cupra-ammonium Cotton Solution Mixer	532
112. Filter Presses	534
113. Centrifugal Pot Spinning Stretch Method	538
114. Stretch-spinning Device	539
115. Reel-stretch Spinning Machine	542
116. Acetylyzer Mixer for Cellulose Acetate	570
117. Acetate Solution Spinning Machine	576
118. Cerini's Dialysator with Collector	582
119. Cerini Caustic Soda Recovery Plant	585
120. Enclosed Spinning Machine	589
121. } Sulphuric Acid Absorption Process Flow Sheet	592
122. }	
123. Bregeat Solvent Recovery System Flow Sheet	595
124. Solvent Recovery Towers in Nitro-Rayon Plant	596
125. Heat Exchanger	598
126. Continuous Stripping Sill	599
127. Continuous Stripping Sill	600
128. Flow Sheet of Activated Carbon Plant	604
129. Old Hickory, Tennessee	608
130. Du Pont Rayon Plant in Tennessee	609
131. Viscose Company Original Plant at Marcus Hook, Pa.	610

FIGURE	PAGE
132. Viscose Company Plants	611
133. View of the Mill at Chatillon, Italy	615
134. Workmen Leaving Mill at Chatillon	616
135. Control Laboratories at Chatillon	617
136. Tanks at Chatillon Mills	618
137. General View of Ivrea Mills	619
138. Acid Tanks at Ivrea Mills	620
139. Alkali-cellulose Process, Ivrea	621
140. Sulphurizing Department at Ivrea	622
141. Spinning Hall at Ivrea Mills	623
142. Bleaching and Dyeing Department at Ivrea Mills	624
143. Sorting, Grading and Packing Hall at Ivrea Mills	625
144. General View of the Vercelli Mills	626
145. Viscose Ripening Tanks, Vercelli	627
146. Bobbin Drying Hall at Vercelli Mills	628
147. Twisting Hall at Vercelli Mills	629
148. Reeling Hall at Vercelli Mills	630
149. Power and Transformer House at Vercelli Mills—Interior	631
150. Power and Transformer House at Vercelli Mills—Exterior	632
151. Arnheim Plant of Dutch Enka Company	633
152. Ede Plant of Dutch Enka Company	634
153. American Bemberg Rayon Plant	636
154. Rayon Skeins	638
155. Bobbins. Rayon Yarns Ready for Use	642
156. Winding Machine for Winding Rayon from Spools onto Bobbins	643
157. Winding Machine for Winding Rayon from Skeins onto Bobbins	644
158. Winding Machine for Winding Rayon from Spools to Paper Cones for Knitting	645
159. Winding Machine for Winding Rayon from Skeins to Paper Cones	646
160. Ways Sizing Machine	649
161. Warping and Beaming Machine	655
162. Lucas-Lamborn Rayon Weaving Loom	656
162A. Spring Needle Knitter	661
163. All Rayon Sheers	671
164. All Rayon Crêpes	673
165. All Rayon Satins and Twills	677
166. All Rayon Fabrics—Miscellaneous	678
167. Rayon and Silk Fabrics	680
168. Rayon and Silk Fabrics	682
169. Rayon Warp-wool Filled Fabrics	683
170. Rayon and Wool Combination	686
171. Rayon and Wool	687
172. Rayon and Cotton	689
173. Rayon and Cotton	690
174. Rayon Containing Modern Art Fabrics	692
175. Buhlman Skein Dyeing Machine	699
176. Titering or Numbering Apparatus	719
177. Electrically Heated Conditioning Oven	720

ILLUSTRATIONS

xxiii

FIGURE	PAGE
178. Apparatus for Testing Strength and Elasticity	722
179. Twist Counter	723
180. Inspection Apparatus for Uniformity and Purity	723
181. Soxhlet Apparatus for Determining Fat in Cotton	733
182. Apparatus for Determining Copper Number of Cellulose	734
183. Apparatus for Determining Nitrogen in Cotton	739
184. Accurate Type of Titration Apparatus	739

THE RAYON INDUSTRY

CHAPTER I

HISTORICAL

“RAYON”—the new name for a once ridiculed and rejected product! “Rayon”—the first synthetic textile—lustrous, gleaming and radiant with light, which has become more adaptable than silk! The word “Rayon,” adopted only three years ago to designate the product formerly known as artificial silk, is now a word of the dictionary of the English language and there are few today who do not know what the word “Rayon” stands for.

There is a vast amount of romance, heartache, herculean effort, indefatigable labor, disappointment, joy and achievement behind its story, which must be left largely to the reader's imagination in this necessarily brief outline. We shall briefly trace the steps from its conception; through its production as a laboratory curiosity; its struggle to gain a place as a commercially possible textile fiber; and finally to its overwhelming and almost miraculous success, its acceptance and its winning of a secure position among textile fibers, even now ranking third in the list of those which clothe and decorate the human race.

The idea of producing an artificial silk by mechanical means, now known as Rayon, was first produced in the middle of the seventeenth century and subjected to examination by

the eminent English scientist, Dr. Robert Hooke, whose views were published in the year 1664. He propounded the prophetic statement "I need not mention the use of such an invention nor the benefit that is likely to accrue to the finder." René A. F. Réaumur, a French physicist and naturalist, in 1754 proposed the possibility of making artificial silk in his "Histoire des Insectes." In fact the prophecy that silk would be imitated by human artifice, which would some day set up a factory to do what the silk worm does, is explicitly stated by Réaumur in the following words:

"Silk is only a liquid gum which has been dried. Could we not make silk ourselves with gums and resins? This idea, which at first sight might appear fanciful, is more promising when examined closely. It has already been proven that it is possible to make varnishes which possess the essential qualities of silk. China and other varnishes are unaffected by solvents; water has no effect on them; the greatest degree of heat to which our fabrics are exposed could not change them. If we had threads of varnish we could make them into fabrics which by their brilliancy and strength would imitate those of silk and which *would equal them in value*, for good varnishes when properly dried have no smell. But how can we draw these varnishes into threads? We cannot, perhaps, hope to draw out the threads as fine as those obtained from silk worms, but this degree of fineness is unnecessary and it *does not seem impossible* either to spin them into threads, or to spin them *even as fine as natural silk*, when we consider to *what an extent art may be carried*."

From 1740 to 1840 little of significance was done in the field of artificial silk, until the appearance of the great invention of the mechanical process of producing wood pulp by F. G. Keller, a Saxon weaver of Hainichen. The importance of his invention was recognized by those who came after him.

During the same period that Keller made his fundamental invention of wood pulp Louis Schwabe of Plymouth

Grove, Manchester, an owner of silk mills and maker of patent embroidery machines, was experimenting with substances which could be "drawn out through fine holes into filaments or threads." Schwabe was thus the first to exhibit a machine in Manchester for producing artificial silk, which is practically the vanguard of the rayon spinning machine of today. He was also the first to suggest the spinneret. Unfortunately he could not get the assistance he needed and died by his own hand a disappointed investigator.

None of the then existing "substances" lent themselves to successful fibre production, but the search for a satisfactory filament became intense and numerous inventors in seeking the desired result led to the discovery of nitro-cellulose by Schoenbein in 1845 and the study of its properties when attempts were made to produce threads which should imitate silk. One of the earliest experimenters with this new nitro-cellulose was Audemars of Lausanne, who as early as 1855 took out a patent for transforming dissolved nitro-cellulose into fine threads which he at that time called "artificial silk." But from a textile point of view, little progress was made until the successful and epochal work of Count Hilaire de Chardonnet. There were, of course, others whose earlier work contributed to the successful manufacture of artificial silk, such as Hughes, Swan, Powell, Evans and Wynne, Crookes, Swinburne and Weston, but it remained for Count Chardonnet to culminate the entire efforts of his predecessors, and his labors have justly won for him the title of the "Father of the Rayon Industry."

Count Hilaire de Chardonnet was a purposeful research worker equipped with the education and training of the École Polytechnique, and his discovery was not the result of alighting on a bright idea by mere chance; it came after long study of the definite ways and means whereby a specific thing might be accomplished. While a student at the École, Chardonnet

was a pupil of Pasteur, the master bio-chemist, who was at that time engaged in a study of the diseases of the silk worm.



FIG. 1. Count Hilaire de Chardonnet (1840-1924).

In many thousands of years it had been a matter of common knowledge that the silk worm fed on the leaves of the mulberry and that of the oak, and that the worm exuded a gum

in the form of a fine continuous filament with which it surrounded itself, forming the cocoon. From this cocoon, by methods as old as history itself, has been made the fabric which has been regarded from time immemorial as the cloth of kings and the favored few, and the only suitable raiment for all occasions of importance.

The natural step, then, for this discoverer, equipped with his laboratory experience and his knowledge of chemical science, was to imitate as closely as possible the processes of the silk worm in cocoon formation. Since the principal constituent of the leaves on which the silk worm feeds was found to be cellulose, what more natural course, than to endeavor to convert, or digest, the cellulose to some soluble form, press this dissolved or digested cellulose through a small orifice as the silk worm does, and regenerate an insoluble form of cellulose by contact with air or some regenerating liquid? This was the general principle which Chardonnet followed.

Preliminary investigations dating from 1878 formed the ground work upon which the technical and scientific foundation of Chardonnet's principles were laid. Many years were spent in studying the life, the habits and the secretions of the silk worm. The chemical character of the leaves and the trunks of the mulberry tree were carefully studied, and their constituents carefully noted. In 1884 Chardonnet produced his first synthetic fibre, using pulp obtained from the trunks and limbs of the mulberry tree as his chief raw material.

In his memoir to the French Academy of Science in that year he described this fibre as an artificial textile material *resembling* silk. Note that he did *not* call it "Artificial Silk." The Academy granted him a "pli cachete" and under its protection Chardonnet proceeded to work out his invention on a commercial scale. Five years later, in 1889, he was able to exhibit publicly an important collection of specimens of his

product. This public exhibition was sufficiently impressive to attract the attention of capitalists, who provided funds for the erection of the world's first artificial silk factory at Besançon, Count Chardonnet's home town in northern France.

Within two years the technical difficulties of large-scale production had been overcome, the problem of denitrating the cellulose and rendering it non-explosive had been solved, and the company was earning profits and showing and selling an imposing array of goods. The original factory of Chardonnet at Besançon continued to operate successfully until 1914 when it was converted to the manufacture of gun cotton by the French Government. After the World War the factory was sold to European associates of the Du Pont interests, who remodeled it and are continuing the manufacture of Rayon there today.

So was the infant Rayon industry born, and so it grew, from a production of a few thousand pounds in 1900 and one factory, to 265,000,000 pounds in 1927 and 350,000,000 pounds in 1928 and about one hundred factories. The development in Europe was steady and rapid but very little of the new textile fiber found its way to America until 1910. Even in 1912 only a million and a half pounds of Rayon were imported and American production was practically *nil*. In 1927 16,000,000 pounds of Rayon was imported into the United States while approximately 265,000,000 pounds was produced during the same period.

Count Chardonnet died in Rome, on March 12, 1924. He had been a vigorous, energetic and indefatigable worker, such a personality as the creation and establishment of a new industry needs. It was given him in the long years of his fruitful life to see his products universally accepted, to see his new textile standing on its own merits—an article of luxury and beauty, yet within the reach of all—and to see

the establishment of an industry of tremendous potentiality to bless and benefit mankind.

We shall attempt here only to classify the principal processes in the order of their development and point briefly the causes which led to their success. Later chapters will deal with the separate processes in detail.

The Chardonnet, or pioneer process, called more frequently the nitro-cellulose process, consists of converting cellulose (cotton, wood pulp, etc.) into nitro-cellulose or gun cotton. The nitro-cellulose is then dissolved in a mixture of alcohol and ether. The resulting solution is then filtered, aged and then forced under high pressure through capillary orifices or spinnerets forming the thread, under conditions favorable to solvent recovery. Several of these are grouped together, passed through guides and wound on bobbins as Rayon yarn. The Rayon is then dried, denitrated with alkaline sulphides, bleached, washed, twisted and reeled or skeined. The fiber is lustrous, strong and elastic.

The first successful modification of the Chardonnet process was that of Lehner who established his plant in Switzerland. The only important difference was that Lehner coagulated the cellulose nitrate thread in a water bath instead of depending simply on the evaporation of the solvents, alcohol and ether, in air. The successful operation of the Chardonnet and the Lehner process plants soon attracted the attention of chemists to the possibilities of other processes.

The first alternative process to make its appearance was the cupra-ammonium process of Despeisses, first announced in 1890. The mechanical steps of the process were quite similar, but the chemical steps differed in various details due to the nature of chemicals used. Cellulose is dissolved in ammoniacal copper oxide. The solution is then passed through capillaries or spinnerets into a mixture of sulphuric acid and

water, wound on glass bobbins, re-washed in acetic acid, dried, wound and reeled. The resulting fiber is strong, lustrous and elastic.

The original cupra-ammonium process of Despeisses was modified in chemical and mechanical details by Pauly, who first demonstrated his process successfully at Gladbach. He attracted capitalists of the Mulhouse region and there came into being the rival "Glanzstoff Fabriken" at Elberfeld about the year 1897. Fermery, Bonnert and Urbain made notable contributions to the successful technical developments of the cupra-ammonium process, the establishment of which, while not important from a standpoint of volume of production, is important both technically and from the standpoint of the quality of the product.

The next technical advance of importance was the development of the Viscose process. The discovery of the chemical processes underlying the Viscose method came about through a special study of alkali-cellulose and mercerizing reactions conducted by Messrs. Cross and Bevan in 1892. The basic new product was alkali-cellulose xanthate, which the inventors called "Viscoid." This product was formed in two stages of synthesis: First, digestion of cellulose in alkali, then converting to a water soluble thiocarbonate by treating it with carbon bisulphide.

Much was expected of the financial and industrial importance of this product at the outset and a holding and development company, Viscose Syndicate, Ltd., was formed and later the Continentale Viscose Gesel. m. b. H. was organized for the general control of patents and further development. A study of the spinning capabilities of Viscose was undertaken about 1895 by C. H. Stearn and C. Topham for the special purpose of determining the adaptability of carbonized Viscose threads to incandescent lamp manufacture. This work was done at the Incandescent Lamp Works at Zurich, Switzerland.

The ample measure of success which attended their efforts led to the formation of the Viscose Spinning Syndicate, which set out to determine how the Viscose method could be extended to the production of textile threads. An experimental plant was erected at the Kew Works of the Zurich Lamp Company and the long, tedious and often discouraging journey was begun.

The objects of the research conducted at the experimental plant were:

(1) To determine the most suitable major raw material—cellulose.

(2) To determine the best conditions of stability for cellulose xanthate, which has the very troublesome tendency of spontaneous and progressive decomposition and reversion to cellulose.

(3) To determine the best conditions for controlling thread formation.

(4) To determine the best conditions of spinning the threads and all accessory processes in order to give threads of uniform weight, maximum luster and softness and best weaving qualities—namely, strength and elasticity.

It was the spinning and twisting of the individual unit Viscose threads into a single cohesive fiber which proved most troublesome in attaining quantity production. On this phase of the problem Topham developed his memorable and epochal centrifugal spinning box—a stroke of genius which effectively solved the problem and started the Viscose Rayon process on its road to supremacy. The Topham centrifugal spinning box or pot is an apparently simple device which rotates at about 5,000 to 10,000 revolutions per minute. Viscose liquid is forced under pressure through the orifices of the spinneret into the setting bath, from which 16 or more unit threads are led up over a glass roller or Godet, from which they drop vertically into the “Topham” box. The centrifugal force of

the rapidly rotating spinning box produces the following desired effects simultaneously:

- (1) The forward draw of the thread.
- (2) The necessary twist of the multiple unit thread into yarn.
- (3) Building up a tightly wound annular mass—a typical cocoon—from which the yarn can be wound into skeins with ease and but little loss. This is called the Rayon cake or cheese.

From this time on the development of Viscose industries was rapid and then secured the backing and support of Samuel Courtald & Co., Ltd. However, many discouragements and failures were encountered in the first licensing and establishment of plants, and failure attended the early efforts of Viscose companies in England, Germany and the United States. The first exhibition of Viscose rayon goods occurred in Paris in 1900. By 1912 we find Viscose companies in the United States and Europe progressively solving their technical difficulties so that today they lead in capitalization and profit-making and supply more than three-fourths of the world's output of Rayon.

The rapid and remarkable growth of the Viscose branch of the Rayon industry may be laid indirectly to the development of the "Topham" box; the calibre and character of the research workers who had solved different problems; and the faith, vision, liberality and strength of its financial backers. The direct cause of the growth of the Viscose process may be found in the fact that the materials required are cheap, of world-wide distribution, and therefore no expensive and troublesome recovery processes are required.

The next process to be developed commercially was the cellulose acetate by the British Cellulose and Chemical Manufacturing Company, whose product is known to the trade as "Celanese." Cellulose acetate was first prepared by

Naudin in 1869. Cross and Bevan (1890-1894) first attempted to use these acetate of cellulose esters commercially, but their acetylation process was soon displaced by that of Lederer. Workers in the United States, namely, Little, Mork and Walker also made interesting contributions to cellulose acetate technology. In Germany the cellulose acetate art was also considerably advanced by the work of Bayer & Co. and Knoll & Co.

Nevertheless the comparatively recent acetone soluble cellulose acetate of H. Dreyfuss is the present basis of the "Celanese" industry. In fact, it can be truthfully said that the "Celanese" industry really dates from post-war times. It so happened that the huge factory located at Spondon, England, developed during the World War for making the familiar "dope" used for dressing aeroplane wings, was faced with serious loss at the close of hostilities. The "dope" was the Dreyfuss cellulose acetate. To convert the "dope" factory of the British Cellulose & Chemical Manufacturing Company into a peace-time pursuit commensurate with the size of the plant and the capital involved, was the problem. The most promising field was Rayon, and after many difficulties, technical, industrial and financial, Messrs. H. and C. Dreyfuss, with the assistance of A. Clavel and J. F. Briggs, finally placed "Celanese" on a practical and profitable footing. Beginning with the early part of 1928, various acetate silk companies have been organized in the United States and other countries, based on claims representing modifications of "Celanese" produced by the British Cellulose & Chemical Manufacturing Company and its other subsidiaries. Among them are The British Acetate Silk Corporation, Ltd., and the recently organized company "The Cellulose Acetate Company, Ltd.," which is building its first plant at Lancaster, England. The DuPont Rayon Company is erecting its first American acetate Rayon plant for a capacity of three to four million pounds

per year. The American Viscose Company is also completing its acetate Rayon plant for a capacity of about three and a half million pounds per year and the American Chatillon Corporation its two million pound acetate plant at Rome, Ga.

Before reaching the more advanced stages of process discussion, the steps in the four principal processes for Rayon manufacture are briefly summarized in flow charts Nos. 2, 3, 4 and 5.

The first three processes, the Viscose, the Nitrocellulose and the Cupra-ammonium may be said to be regenerative in that the final product is in reality a pure Cellulose (Rayon) reconverted from original cellulose raw material, while the fourth, the Acetate process, is non-regenerative in that the final product is a conversion product of the original cellulose material. Further details of the processes and a comparison of the properties and uses of the four kinds of Rayon will be given in later chapters.

There is no accurate data available which gives the percentages of Rayon produced under the different processes. It is estimated, however, that for 1925 and 1928 the world production by processes was approximately as follows:

	1925	1928
Viscose	76%	84%
Nitro	18	9
Cupra-ammonium	5	5
Cellulose acetate	1	2

The author stated in his previous edition that: "Prophecy is hazardous but it would seem that with the financial strength behind the cellulose acetate group, the ramifications of their interests into the manufacture of dyestuffs, together with the superior quality of the product, may result in an early stimulus to this process. There is also the fact that the dyeing qualities of this brand are stimulating demand." Since

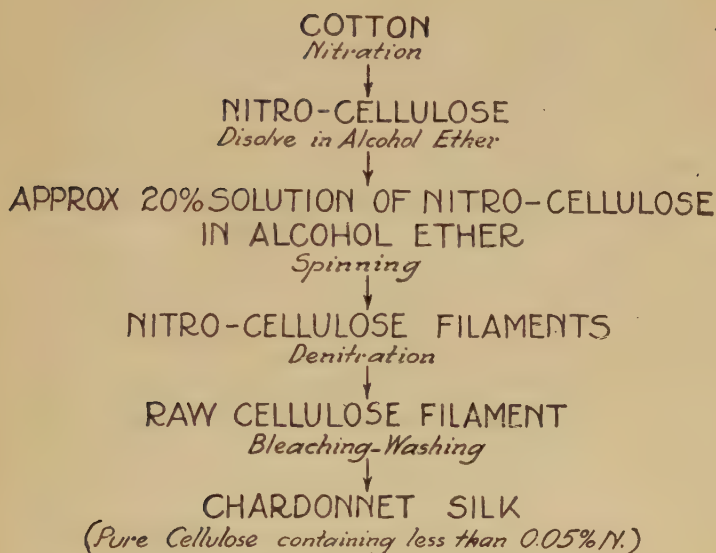


FIG. 2. Condensed Flow-sheet of Chardonnet or Nitro Process.

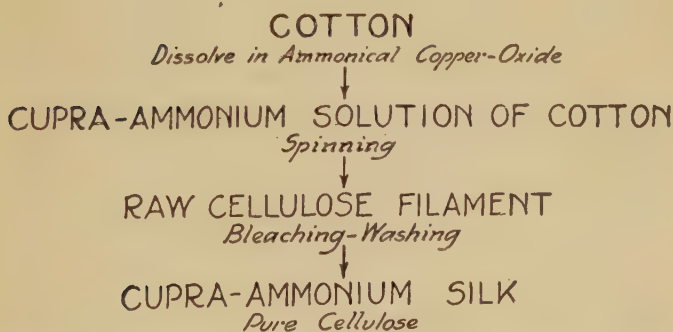


FIG. 3. Condensed Flow-sheet of Cupra-ammonium Process.

THE RAYON INDUSTRY

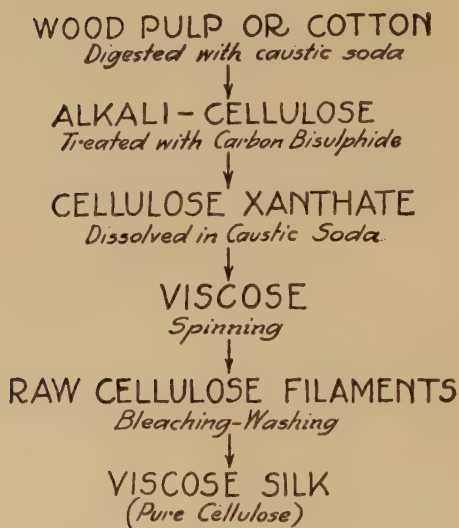


FIG. 4. Condensed Flow-sheet of the Viscose Process.

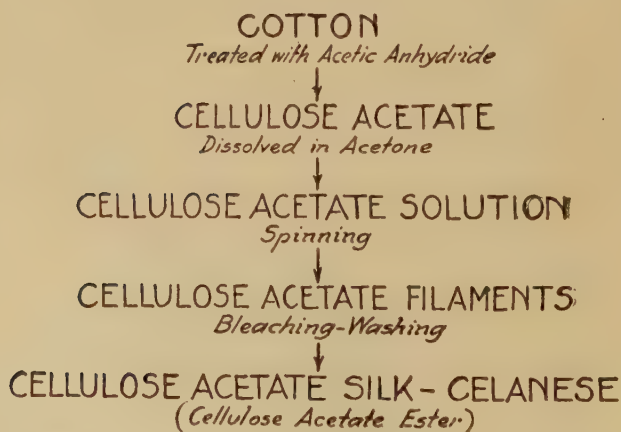


FIG. 5. Condensed Flow-sheet of the Cellulose Acetate Process.

that statement was written, only two years ago, the Cellulose Acetate group, known as the Celanese Corporation of America, has attracted financial alliances of outstanding character which have strongly reflected in the prices of the securities of this corporation. But phenomenal as the growth of this acetate group was, the other processes have not lagged in the least. Such outstanding progress of this one corporation has also reflected itself in the agitation for more acetate silk plants, some of which will be in operation by the middle of the year 1929.

The wonders of technology never cease and in case of the discovery of hitherto unknown solvent methods or recovery methods, or mechanical methods, any one of the other processes might forge ahead, overcoming, or at least shortening, the lead which the Viscose method now enjoys because of its natural advantages.

In these days of rapid technical advance, it would be folly to place any limitation whatever on human accomplishment when we stop to consider the marvels which have been unfolded and developed to date.

The impossible of yesterday is the "fait accompli" of today. The difficult and unsurmountable things have thus been overcome showing with what openness of mind we should attack the problems which confront us, refusing to be bound by the traditions or rules of the past and firmly believing that all things are possible to the mind that searches diligently for truth.

CHAPTER II

IMPORTANCE AND GROWTH OF THE INDUSTRY

FOR years after its successful commercial production, Rayon labored under the handicap of the misnomer "artificial silk," which carries with it the implication that it is a substitute for real silk. Substitutes are always regarded as falling short of their original in quality, and therefore the unfortunate name "artificial silk" carried the suspicion that an inferior product, of which he should beware, might be foisted on the buyer. This situation, of course, reacted upon Rayon to its detriment as if the product were attempting to assail the position occupied by silk, and the ultimate aim of its producers was to displace the raw silk industry.

Fortunately, the mind of the general public and that of the textile world has been disabused of this fallacy through the efforts of Rayon manufacturers, who gradually impressed users with the fundamental and basic differences between the two fibers and worked tirelessly to show that Rayon was not the antagonist of any textile fiber but the ally and complement of all. Realizing the retarding influence of such a misnomer as "artificial silk," several manufacturers individually proposed such names as "glanz," "lustron," "fibre silk," "art silk," etc., but none of these met with general approval. Finally, at a meeting of American manufacturers in 1924, and largely through the efforts of Mr. S. A. Salvage, President of the Viscose Company, the name of "Rayon" was adopted as the official trade name of their product. The name is euphonious and descriptive and may be said to convey the

meaning of the radiance of bright sunshine, tempered with the soft glimmer of rippling waters in moonlight.

Then followed the work of getting the name officially recognized by the various textile associations and finally by the Federal Trade Commission. This latter was accomplished in October, 1925. It is interesting to note that in just a little more than three years' time the name "Rayon" had "caught on" and had conquered every phase of the textile business—weaving, knitting, dyeing, wholesale and retail distribution. The name has been registered throughout the world for the purpose of protecting its use for the public and preventing any private appropriation or improper use.

It seems altogether likely that with the growing importance of the American group as factors in the industry, the name "Rayon" will be impressed and adopted throughout the world. In passing, it is interesting to observe that the industry has had its most remarkable period of growth since 1924—the year the alluring, and imaginative name "Rayon" was adopted. Now, in the year 1929 only four years since the name "Rayon" has been adopted, it is known to everyone. Where in previous years manufacturers, jobbers and retailers were not willing to acknowledge the use of Rayon, now they not only acknowledge it but are glad to advertise the fact. The public not only knows what "Rayon" is but is rapidly learning how it is used. To disseminate this knowledge to the ultimate consumer the Rayon Institute was recently formed. This, aside from all advancement made in the production and use of Rayon, is of greatest importance for the commercial progress of the Rayon Industry.

This remarkable growth of the Rayon industry has had the effect of strengthening, rather than crowding out, its companion fibers—silk, wool and cotton. Rayon has widened the use of each of these through the creation of new combinations of fabrics which are reasonably priced and yet more

attractive and beautiful than any others hitherto offered. Therefore, instead of being a destructive force, Rayon has proved itself a constructive force, which has stimulated and stabilized the entire textile industry.

Rayon is the one textile fiber not subject to the whims of nature; it is produced under human control and therefore no wide or sudden fluctuations in supply or in price are possible. As demand increases, manufacturers find it profitable to increase their output to meet it. The factors of stability of price and assured supply, together with the adaptability of the fiber for varied use with other textile fibers, make Rayon a real balance wheel in the entire field of textile production—cotton, silk and wool. Therefore, Rayon is no longer the despised stepchild of the textile family, but a welcome accepted member of the real circle.

RAYON PROGRESS HERE AND ABROAD

The progress in Rayon production is so rapid that even one year will make a difference. Between the years 1925 and 1928 great strides were made in all phases which have had to do with Rayon, such as its production on the one hand and its use on the other. As a comparison of opinions we will give first those expressed by leading Rayon authorities in 1925-26 and by the same ones in the year 1928.

The Textile Division of the United States Department of Commerce in 1925-26 summarized this growth as follows:

"Despite the great increase in production, the manufacturers have been unable to satisfy the demand for Rayon, and the industry is experiencing a period of rapid development in practically all of the important manufacturing countries of the world. In the United States, the production and consumption of Rayon continued their steady growth during the current year.* The output of the American plants for the first half of 1925 is

* Production for 1925 was reported as 53,000,000 pounds.

reported as slightly over 24,000,000 pounds, and as they have been working at capacity all year, their annual production is estimated by trade sources to be in the neighborhood of 50,000,000 pounds. This figure shows a remarkable increase over the output of recent years. In 1920 the American plants produced 8,000,000 pounds, almost doubling the output in the following year to 15,000,000. The year 1922 showed a further increase to 24,000,000 and in 1925 this amount was produced from January to June.

"Figures compiled by important Rayon manufacturers show that the knit-goods industry was the largest consumer of Rayon, taking 25 per cent of the entire American consumption in 1923. The hosiery manufacturers followed with 22 per cent, and considerable quantities were taken by the cotton mills, silk mills, and other branches of the textile industry. One important advantage to the consumers of Rayon is the price stability. The producers announce their prices for the coming quarter, open their books for orders, and allot their output. During a considerable portion of 1925 premiums were paid for immediate deliveries of yarns.

"The competition of foreign yarns with the producers in this country is dependent chiefly on the American supply available for consumption. In 1922 the importation totaled 2,088,000 pounds. In the following year they amounted to 3,906,000, almost double the takings of 1922. This was followed by an appreciable price cut by the principal American producers, which resulted in greatly reduced imports in 1924. In 1925, however, the inability of the plants in the United States to supply the demands for the fiber resulted in the importation of over 5,000,000 pounds valued at \$5,769,925, which was approximately one million dollars less than the value of the 1923 imports which, however, only totaled 3,906,037 pounds.

"France, which is the old European home of the natural silk industry, has now a well-established Rayon industry. Until recently this industry was localized in the South, but it has now become well rooted in the Roubaix-Tourcoing woolen textile district of the north. Notwithstanding the large output of the French works, it is absorbed almost entirely in the country.

"England has not been slow to make Rayon production one of its important textile branches, and the cotton and wool textile circles have become large users. The first manufacturers have

increased their productive capacity up to the extreme limit, and new factories are frequently being built. One of the largest English producers has started a branch of the works in Canada, India and other countries.

"In Germany the break-up of the munition manufacturing industry after the War provided the stimulus for the establishment of the Rayon industry in order to keep factories employed. Since then the industry has prospered, and at present is in a much better position than the other textile branches in Germany. Quite remarkable is the development of the industry in Italy, where it is favored by cheap and capable labor, water power, and a home production of the necessary chemicals. This country has attained in about four years a powerful position as a manufacturer and exporter of Rayon. The consumption in Italy is mainly of the home product, and each year that passes sees an increasing surplus for export.

"The Japanese annual demand for Rayon is increasing steadily and at present amounts to 3,500,000 pounds. At first consumers in Japan did not seriously consider the use of the artificial product, due to the fact that the cultivation of the silk worm is a national industry on which the prosperity of the country depends, and naturally anything that retarded the production of silk was looked on askance. Due to lower prices and increasing popularity of Rayon, not only were large quantities imported but its manufacture in Japan on a large scale is now assured."

RAYON'S FUTURE

In line with the opinions of others who are able to estimate the future of Rayon, the author stated in his 1926 edition of this volume the following:

"The progress of the newest textile industry—Rayon—has been remarkable, but the really sensational developments undoubtedly lie in the future—perhaps in the immediate future. The manufacture of this fiber is now so remunerative an enterprise in several branches that vast sums of money are available for research, and it is not too much to hope that quick progress will be made in cheapening the cost of production, increas-

ing the tensile strength of the fiber, especially when wet, overcoming some of the difficulties of combining it with other textiles, and also reducing the tendency of Rayon fabrics to retain creases. Although the mass production of Rayon is now turning more and more to the Viscose process there is already an invigorating competition from other processes. So far the synthetic fiber is only an interesting and valuable supplement to the natural fiber. It has a long way to go before it replaces them. The future of the Rayon industry has been well expressed by some of the leaders in the American Industry. Their visions for the future are contained in the following statements:"

L. A. Yerkes, President, Du Pont Rayon Company:

"We are optimistic in our outlook for 1926. Generally speaking, the textile world is in better condition than it has been for several years. This applies, of course, particularly to the cotton industry. The uses of Rayon are broadening continuously, and we can see no reason why 1926 should not show an advance in poundage consumed comparable with previous years. There will probably be 60,000,000 pounds at least produced in this country during the year 1926, and we believe it will be absorbed without difficulty.

"The imports are heavy but not sufficiently so to cause undue anxiety at this time. This phase of the matter, however, needs watching. This time of the year there is always a slight lull due to stock-taking, etc., but we look for an improved market after the turn of the year and to a good substantially increasing distribution through 1926."

Bertrand R. Clarke,* Vice-President, Tubize Artificial Silk Co. of America:

"The year 1925 has again demonstrated the need in modern textile industries of a stimulus which only artificial silk has been able to give. The remarkable increase in poundage of the various

* Bertrand R. Clarke has since been President of the Industrial Rayon Corporation, and is now managing director of the Cellulose Acetate Silk Company, Ltd., of Lancaster, England.

producers, during the past year will again be increased during 1926, but we have noticed that whenever seasonal activities or style changes have reduced consumption of our product in one quarter it has been more than taken in industries already using it, and in new ways developed for its use.

"There has been a great deal of conversation and a great deal written during the past year about the expansion plans of new companies, but inasmuch as the difference between conversation and performance is quite marked in this industry, we do not expect to see more production in 1926 than will be comfortably and readily absorbed. Conditions in the trade, so far as demand is concerned, during the first quarter, augur well and our books at this time are practically closed."

Dr. Camille Dreyfus, President, American Cellulose & Chemical Manufacturing Company, Ltd.:

"The year just closing has been an exceedingly interesting one for the American Cellulose & Chemical Mfg. Co., Ltd., our works at Cumberland, Maryland, having come into production at the early part of the year, and from a very small beginning have now grown to quite substantial proportions. The demand for 'Celanese' has been a most gratifying one, and our yarns are now being used in every branch of the textile industry, such as in the underwear, hosiery, ribbons and broad silk trades, and also in the fabrics made of either mixtures of 'Celanese' and cotton or 'Celanese' and Rayon. We produce yarns from 45 to 300 denier with fine filaments and also produce some super-extra yarns in 75 and 150 denier.

"The outlook for the coming year seems to us a very bright one, and we are already well booked up for the early months. Our production is steadily increasing, but we are notifying all our clients that they should give us as much advance notice of their requirements as possible in order that we may take care of them. The production of Rayon for 1926 is estimated at between fifty and sixty million pounds."

S. A. Salvage, President, Viscose Company:

"The Rayon Industry for the year 1925 has been through a period of unparalleled activity which has not as yet approached

its climax. The consumption of Rayon, which has steadily increased each year since its introduction, surpassed all previous records and established a place for itself with the age-old textile fibers of the world—silk, wool and cotton. This steadily increasing activity in Rayon uses has not been due to the dictates of fashion, but rather to the accumulative results of its appreciation by the consuming public, who more and more realize that fabrics made from Rayon combine the three desired features—price, attractiveness and wearing qualities. One can look forward with confidence to an increasing demand for Rayon during 1926, as records show that especially in cotton and underwear lines there is an unprecedented demand.”

Excerpts from a statement of W. W. Birge, President of the Industrial Rayon Corporation follow:

“Production increased during 1925 at a rate never equaled and I believe never even approached, but in spite of this there was during most of the year, at least, a small under-supply. This was particularly true during the first part of the year. During the last half of the year, quite largely as a result of the drought throughout the South, which necessitated putting many of the textile plants in that section on a part-time production basis, the consumption of the higher grades was considerably reduced and as a result of certain style changes, which resulted in a falling off in the braid and fringe trade, the consumption on the lower grades was also reduced during the latter half of the year. In spite of these reductions in consumption there was at no time more than a reasonable supply of Rayon in the hands of the producers.

“There has never been a time when the public at large, and textile mills in particular, have given as much thought to the production and consumption of Rayon materials as has been given during the past year. My observations lead me to the conclusion that the year 1926 will find a greater increase in the consumption of Rayon than has been experienced in any previous year. The major consumption of Rayon has been in the different branches of the knitting industry and with the possible exception of the knitted outerwear industry I believe that this consumption will continue to increase, but if my information is correct, I

believe that the weaving industry, particularly the cotton mills, will equal in consumption the large amounts which in the past have been consumed by the knitting industry, and I am convinced that this new source of consumption will during the year 1926 take care of any possible increase in production."

Mr. N. Y. Tagura, who finances about one-fourth of the raw silk that leaves Japan each year, made an interesting statement in 1926 which has some bearing on the future of Rayon. It was his opinion that Rayon would soon be the more predominant of the textile yarns. Mr. Tagura further said that because the world wanted more and cheaper garments instead of fewer high priced ones, sericulture, even in the Orient, would give way to Rayon production.

After a short period of only two years authorities express their opinions of the Rayon situation as follows:

The Textile Division of the United States Department of Commerce, summarize as noteworthy the growth of the industry in 1927:

"The year just passed was one in which remarkable strides were made in the Rayon industry. This progress was particularly notable in the United States where all previous records of production were broken, imports reached a new high level, with consumption making even greater relative gains. In addition, there was a definite movement toward the production of finer and better yarns and fabrics.

"New enterprises were started, new units of existing plants were built and put into operation, improvements were made in manufacturing methods, all of which resulted in increased capacity of American plants. Various estimates have been made as to the amount of yarn produced during the year, most of which place it at approximately 75,000,000 pounds. This figure represents a 21 per cent increase over the previous year.

"Notwithstanding the enormous output of domestic manufacturers, the imports of foreign yarns increased from 10,063,068 pounds in 1926 to 16,222,572 pounds in 1927. Italy, which re-

placed the Netherlands as the most important supplier of imported yarns, furnished over 41 per cent of this total.

"The domestic consumption has been variously estimated by the trade at over 100,000,000 pounds for the year. This figure is particularly impressive when compared with the 1926 consumption of approximately 62,000,000 pounds, and indicates that the tremendous growth of this industry was not predicated merely on a passing fancy for something new in the line of textiles.

"Trend to Finer Grades: An examination of a composite trade statement recently published shows that while there was but little change from the previous year in the ratio of the various sizes of yarns produced there was undoubtedly a tendency toward the production of the finer denier yarns. The production of 150 denier yarns showed a slight decrease, while a still further decrease was noted in the 300 denier class with corresponding increases in the remaining sizes.

"In examining an analysis made of imported yarns it is noted that out of the total of 15,307,202 pounds of rayon yarn singles imported into New York during 1927, slightly over 79 per cent represented 150 denier yarns and 13 per cent 300 denier yarns. Out of the total 12,122,713 pounds of 150 denier yarns imported during this period, 'A' grade accounted for slightly less than 44 per cent, and 'B' grade approximately 45 per cent. In the 300 denier class, approximately 46 per cent were 'A' grade yarns and 42 per cent 'B' grade.

"More Used in Underwear: While the ratio used in the knit goods industry as a whole remained approximately the same as it did the previous year, there were increased amounts used in the underwear branch of the industry with a corresponding decrease in the hosiery branch. The percentages used in cotton and silk mixtures showed practically no change.

"One of the interesting features of the year was the even price level maintained in spite of the enormous demand for this fiber. With other textile raw materials showing rather wide fluctuations one is impressed with the price stability of rayon. While premiums were paid at various times for delivery of the sizes most in demand, the official prices of producing companies

remained constant for 150 denier yarn after a slight increase of five cents per pound in March.

"Improvements Sought: It is significant to note that in spite of the fact that producers were unable to keep abreast with the demands for this yarn, increased efforts were made to bring about improvements in the character of yarns produced. This was particularly noticeable in the endeavor to produce yarns of fine denier. Fabrics manufactured from such yarns attracted considerable attention and it is believed that efforts along this line will continue. A large part of the increased consumption over the previous year can probably be accounted for by the fact that manufacturers were making diligent efforts to turn out better yarns. With the continued improvement in quality came a gradual expansion in the uses to which rayon was put, resulting in greater demands for it.

"One of the outstanding developments in the industry during the year was the determination on the part of certain producers to undertake educational activities among the consuming public and the trade. This work has been apparent in several forms, among which were the formation of institutes devoted to the collection and dissemination of information pertinent on the fibre itself and the uses to which it is put, individual advertising programs, style shows, moving picture films, exhibits, etc. It is apparent that Rayon is gaining increased recognition among the buyers of textile fabrics, and it is believed that as the educational program progresses much of the doubt and mystery at times connected with this newcomer in the textile field will disappear.

L. A. Yerkes, President of the Du Pont Rayon Company, Inc., gives these views for 1927 and 1928:

"The most successful year, from the standpoints of both production and consumption, ever enjoyed by the rayon industry in this country has passed into history. A prevailing optimism underlies forecasts for 1928. Many leaders in textile circles predict an even greater showing by rayon during the current year.

"Yarn producer, fabric maker and converter alike may well marvel at the tremendous strides this new textile has made in

recent years. In fact, we often ask ourselves the perennial question, 'Why?'

"To attempt in this limited space to make a careful analysis of all the factors that have combined to place Rayon on its present plane of success would be to do the industry an injustice. The subject is too far-reaching. It is a job for an economic historian—and it is to be hoped that an adequate study of all factors may soon be compiled, edited and added to the already growing Rayon 'library.'

Trade and Consumer Show More 'Consciousness': However, it occurs to me that there is a contributing factor to this story of success that is sometimes taken for granted. It is the rapidly increasing 'consciousness' of Rayon and Rayon fabrics manifested by the two great outlet groups—trade and consumer.

"Advertising men speak of 'consciousness' as the first, faint symptom of the desire to buy. From their standpoint, a product of which the public is not 'conscious' is a product with dubious prospects for sales success. Millions are therefore spent in advertising to gain 'consciousness' for certain soaps, perfumes, automobiles, dairy feeds and scores of other articles.

"Millions have also been spent by Rayon producers in recent years, to gain 'consciousness' of their product. But these millions have been spent for the most part in developing an industrial experiment into a new textile that is at once serviceable, economical and thoroughly infused with quality. That these millions have been well spent goes without question. Rayon's place today is a direct result of this technical and manufacturing development, and rayon sales today are reaching new heights because the textile trades and the mass of consumers are accepting rayon on its merits.

"To carry this thought further, let us analyze briefly some reasons for this wide and ever-growing acceptance of rayon yarns and rayon containing fabrics.

"Three Early Ailments Now Seen as Overcome: There is no denying that in the early days of its manufacture in America, Rayon suffered from three ailments: namely, its

label as a 'substitute' for something, its novelty, and the poor workmanship displayed in making up Rayon fabrics and garments in the trade. Today, however, the knitters, weavers and converters of Rayon yarns are equally conscious of the real worth of this textile. It has been proved, not by word of mouth, but by performance, to be economical, easy to handle, and easy to work on the machines. Operators, once skeptical, are now enthusiastic.

"Converters, sensing the remarkable properties of Rayon and the effects that may be gained therefrom are bringing out a never-ending stream of new combinations and effects in all-Rayon or Rayon-mixed fabrics. With each successful venture, they gain greater confidence.

"The same confidence permeates into the farthest reaches of Rayon-using mills. Machinery in cotton and woolen mills were easily adapted to handling Rayon, and the operators, long unwilling to deviate from old methods, have now caught the spirit and, in many plants, have become the largest single group of enthusiasts in their respective organizations.

"All this has had its effect on the buying public. Without concerted effort, up to the current year, the Rayon producing and fabricating industries have by sheer faith and enterprise built up in the minds of American men and women a new conception of Rayon materials.

"Institute Second Only to Adoption of 'Rayon': Next to its success in procuring the generic term 'Rayon' for the product, probably the most important step taken by the industry was the recent organization of the Rayon Institute. The institute has already received the co-operation of leading manufacturers. Through its efforts the new and the beautiful in Rayon fabrics are being shown and merchandised to stores and consumers as never before in the history of the industry. Gowns and wraps of Rayon or Rayon-mixed materials are bringing gasps of amazement from women who 'never dreamed they were so lovely.' Paris approves them. American manufacturers and dressmakers are enthused over them, because they are lovely in texture, smartly in the mode and thoroughly serviceable.

"In sponsoring new combinations and new effects, and in acquainting millions of discriminating women with the beauties

of Rayon fabrics as we in the industry know them, the Rayon Institute is therefore capable of playing an invaluable rôle.

"For years Rayon struggled to gain the confidence with which it is now regarded by trade and the public. Preferring to go it alone without governmental protection, the industry has held fast to the solid principles of painstaking research, intelligent workmanship and constant improvement. The men behind it have faith in the economic soundness of the product. That Rayon 'consciousness' is now a fact is perhaps the clearest medium through which to judge the industry."

S. A. Salvage, President of the Viscose Company, forecasts in these words the Rayon situation for 1928:

"The forecasts made the early part of the year regarding the continued activities of the Rayon industry for 1928 have so far not only met, but exceeded expectations, and today The Viscose Co. finds itself completely sold up to early summer, and further, confronted with a demand which it will not be able to meet during this period.

"Announcement was made the other day of a further addition to the Lewistown plant, which will bring this company's production to over 5,500,000 pounds monthly, and some supply from this new unit should be available before the end of the year, and which from every indication will be very much needed.

"The strongest demand continues on the 150 denier, and for the 'A' quality, the highest standard produced, and there is nothing in the market at present which would lead one to believe that there is going to be any change in this situation for some months to come."

Mr. H. R. Mallinson, leading raw silk manufacturer, pays tribute to Rayon:

"Those who thought rayon was the organized enemy of silk are interested in the new door to its future which is being opened by the silk manufacturers themselves, who point to its present co-operative value."

H. R. Mallinson, whose use of this textile has resulted in fabrics such as Orchid Tissue velvet, says:

"Rayon has given to the textile industry a new fiber to blend

with silk, wool, linen and cotton in the creation of original ideas in weaves, colorings and designs. Its luster and other qualities inherent in its scientific construction make it possible for the creative manufacturer to produce fabrics of beauty, individuality and sophistication, and at a price which carries universal appeal.

"In my opinion, the Rayon industry is in its infancy. The possibilities for development and progress, not only in its manufacture but in its merchandising and publicity are practically unlimited. It is just about in the stage of the automobile 25 years ago. If it continues to make the tremendous strides it has since its introduction in this country, it will arrive in a far shorter period at a similar enviable pinnacle of success."

The above opinions from the heads of the leading American Rayon producers are optimistic, and predict a continued natural growth for the industry, while only two years before most of the things that were said of Rayon were confusing and disturbing. Conditions are rapidly stabilizing and Rayon is becoming to be a product much desired and needed for itself when used alone and as a true stimulator for the textile industry when it is woven or knitted with the other textile fibers. Therefore Rayon will continue its vogue without interruption with a demand on the increase from year to year at the rate of 10 to 20 per cent. It is so predicted by the author, and by authorities in the United States and Europe.

Among the European outstanding scientifically progressive Rayon producers is Dr. J. C. Hartog, the managing director of N. V. Nederlandsche Kunstzijffabriek "ENKA" whose views, which appeared in the *Daily News Record* of March 7, 1928, are illuminating:

"Although I do not believe that the increase in the consumption of Rayon and in the production of it can go so rapidly as in the past ten years, I still believe that the regular increase on the one hand in the same proportion as the increase in population and the increasing civilization in Eastern countries and on the other hand with the discovering of new possibilities to use rayon, will be possible for many years. I therefore consider the

yearly increase in the production and consumption at about 15 to 20 per cent; all that will be produced less will cause a deficit of Rayon, while all that will be produced more may lead to a stagnation in the turnover.

"Enka Increasing Production: In the case of my own company, better known as the Dutch Enka Co., for some time past the factories at Arnhem and Ede have been inundated with orders, which it has been a matter of extreme difficulty to fill, despite the factory extensions which have been carried out from time to time. In addition to the plant with which the company commenced operations in 1911 a second large plant has been installed, while another plant, similar to the second unit, is now being built, which will give the Enka Co. a daily production of 50,000 pounds and increase the number of operatives from over 6,000 to 8,000.

"Owing to the limited domestic demand for Rayon yarns and fabrics the Dutch Rayon industry has been almost entirely built up on its export business. While other countries have been largely concerned with the development of the markets in which their works and the works of their subsidiaries are situated, they have, owing to the prime necessity of concentrating production on the fulfilment of domestic requirements, not been able to devote the same energy and resources to the development of overseas markets.

"Export Bulk of Production: The natural result of this has been to force Dutch producers to seek overseas outlets for their products, and in this they have been conspicuously successful. In the last six months of 1927 exports of Rayon yarn from the Netherlands amounted to 3,398 tons, compared with 3,500 tons in the first six months of 1927, representing a decline of 102 tons. In 1927 the production of the Dutch Enka Co. was almost entirely exported, and only a few per cent were retained for home consumption.

"By far the best of the foreign markets as far as the Dutch industry is concerned are Germany, the United States and China. The first named has up to recent times taken the largest quantities, and in the first nine months of 1927 exports to the United States amounted to 1,050,000 kilos, with China accounting for rather more than 500,000 kilos.

"Holland has been watching with close interest the growth of European Rayon cartels and groups of producers, and contrary to the opinion, which has been openly expressed in some quarters, I do not consider that there is a probability of a Rayon war either now or in the immediate future, except as that term may be applied to ordinary conditions of normal, healthy competition.

"While the Rayon industry is young enough to know and be proud of its own strength and the position which it has won, it is, at the same time, old enough to have its slight indiscretions tempered with a little wisdom. For this reason the three groups of producers—viscose, cellulose-acetate, and cupra-ammonium—have learned a sufficient number of lessons from past experience to realize fully that each of these processes has its own reason for existence and that the yarn produced by these different processes has its special properties, making it suitable for various purposes.

"It is realized in Holland that there will always be a tremendous demand for viscose yarn on account of its cheapness and the variety of uses to which it may be put. Cellulose-acetate, on the other hand, has a specialized field in the manufacture of high quality printed and dyed fabrics.

"Sufficient Room for Expansion: It is the duty of the producers to perfect the young Rayon industry. There is sufficient room for expansion and further development of each process, without being afraid that one sort will be superseded by the other.

"Further, there does not appear to be any reason why producers should confine themselves to production by any one method, provided, of course, that they can set up the necessary machinery, buildings, and organization for production by any of the other processes. This is necessarily dependent on the question of patents, and the taking up of the manufacture of rayon by a supplementary process is subject to the provision that no infringement of existing patents is likely to occur. The Enka Co., which up to now has confined its whole attention to the viscose process, specially because the demand for cellulose-acetate yarns, owing to the greater difficulties of dyeing, was small, has in the last year and a half devoted its attention more

to this branch of its business and has taken up some important patents for new inventions.

"Although it has produced up to now these yarns only on a small scale, it is at present engaged in building new factories in conjunction with some other parties, in order to convert the good results which it has obtained in this respect into a commercial product. The Enka Co. therefore believes that it has not too great expectations in mind, if it looks forward quietly to the future of the rayon industry in general and for itself in particular."

Dr. Hartog's statement shows the importance of Rayon to the American market and above all else the need of a continued increase of output from year to year to meet a constantly growing demand. What adds to this demand for Rayon is its silk-like characteristic which satisfies a certain craving of the classes of people who were never able to afford real silk. Rayon, however, is more than a product of luxury at a low price. During the World War the Central Powers found it an article of great necessity.

The growth of the industry aside from all other considerations is due to the constant increase of population. Rayon can be produced, irrespective of climatic conditions, in a limited area with raw materials available at all times. The progress of Rayon has been remarkable not only as to quantity, as to its uses and as to its demand, but also as to the quality of the yarn, in some cases finer than real silk, all of which points the way to better and cheaper textile materials than even cotton or wool.

Considering a total production in the United States for 1926 and 1927, of 60,000,000 and 75,000,000 pounds respectively and 1928 of 100,000,000 and a total world production of 200,000,000, 265,000,000 and 350,000,000 pounds respectively, the question readily arises what becomes of this production. We are witness that it is entirely consumed. One can trace woolen, raw silk, and cotton used materials into

many other channels. But what are the channels of worn-out Rayon garments? They are not reconverted into Rayon yarns and fabrics. Therefore, for the present, Rayon disappears entirely as it is worn and used, so that new production is required annually equal to what was needed the previous year, plus the necessary increase due to additional demand. From this point of view the continuity of life of the Rayon industry is assured.

Considering the increase in the volume of production again we must raise the further question: "What has created this steady growth?" The primary reason is the demand by the public for something similar to silk, at a price it can afford to pay. This demand increased as fast as the public learned that such a fiber was being produced. There are today millions of people who are not yet acquainted with the existence of Rayon and as fast as they learn of it, production will have to increase. Even Japan is producing Rayon and China will soon be producing, for negotiations are proceeding at this moment for plants to be established there.

This Oriental production of Rayon in the countries where raw silk production has thrived for thousands of years is not far short of miraculous, the more so when it is considered that Rayon making in Japan or China is intended not for export but for local consumption. Nearly all European countries are producing Rayon, and few of them have had to export part or all of their production. This indicates that the public sees in its use something which may compare with a fabric of luxury but which can be obtained at a low cost. As long as this attitude lasts (and all considerations point that it will) the public will continue to wear more than the necessary amount of such apparel.

The next reason for the growth of the Rayon industry was the reduction in the cost of production and the lowering of prices to the user—the result of rapid improvements in

the processes and the machinery. These have been due mostly to the efforts of the engineers in charge, and even though the United States leads in production, the American Engineers have not yet sufficiently participated to the end that our own technicians will be credited with increases in productivity and decreases in costs such as always follow our penchant for mass production.

Another reason for increase in the demand of Rayon was the stagnation in the cotton manufacturing field. With the cotton industry in a state of paralysis, it finds in Rayon a means to redeem the cotton industry and as a result special efforts are made to adapt the new fiber to many kinds of fabrics and although the road is difficult the cotton industry is discovering that Rayon proves to be its "Good Samaritan."

The rapid growth of the Rayon industry has given rise to an immense amount of study by many different institutions. Much investigating work is being conducted by technical schools, Rayon producers and Rayon users. The New Bedford Textile School has been conducting experiments and research work for five years. Those in charge of this work are enthusiastic over the possibilities of Rayon. They find that while Rayon has its limitations its larger consumption depends on educating the manufacturer using Rayon, the employee operating the machinery, and the consuming public. Any criticism directed against Rayon has come from those who do not know how to use it. The extent of their activities is such as to lead to the conclusion that Rayon is here to stay.

The Lowell Textile School also conducts lectures and laboratory work on Rayon. The mechanical handling of Rayon and the manufacture of this fiber into yarns is presented to the classes, and considerable instruction is given in the designing and weaving of all kinds of fabrics using Rayon. This institution believes that there will be great improvement and greater utilization of Rayon in the textile industry.

The Bradford Durfee Textile School is making interesting investigations of the new fiber. The most comprehensive test was conducted in conjunction with the Massachusetts Institute of Technology at the instigation of the National Association of Cotton Manufacturers. This test was for the purpose of determining the break and stretch of the different makes of Rayon under various humidity conditions. Approximately 800 different tests were made and all results were carefully charted under relative humidities of 55, 65, 75, and 85 per cent. The results of this work brought out the conclusion that the ultimate breaking strength is not so important as the point where excessive stretch begins. Thus the breaking strength of Rayon cannot be regarded in the same light as that of cotton, owing to the fact, that, for a perceptible time before the final break of the skein, Rayon yarn stretches excessively, which eliminates it for use in some types of cloth. The school has also done much good work on Rayon bleaches, sizes and dyes.

Clemson College, through its textile department offers a one year special elective course in the Chemistry of Cellulose. Lectures and motion pictures regarding the various phases of Rayon production are given.

While Rayon is a comparatively new subject, Clemson College is fully aware of its importance and the prominent place it occupies in all textile manufacturing today. Therefore, no effort is spared to give the student every possible opportunity to become familiar with all phases of the subject, from the actual manufacture of the fiber to its dyeing and finishing in the textile plant.

The Rayon Institute organized recently has as its purpose to provide advice in regard to fabric innovations for technical and research departments of Rayon yarn manufacturers. It proclaims three roads of service, one to the textile manufac-

turers by creating a fuller appreciation of Rayon as it is today; secondly, endeavoring to benefit the manufacturer of Rayon fabrics of all kinds by letting the people know the practical and beautiful ends which these producers have accomplished through the medium of Rayon and thirdly, the making of a direct and convincing approach to the consumer to whom the actual story of the successful development of Rayon is told.

The Philadelphia Textile School has reached the conclusion from its various investigations and tests that it is not so much what one can use Rayon for as *how* one should *not* use it. Some manufacturers of Rayon fabrics pay too much attention to the beauty and design of a fabric and not enough as to how the fabric should be constructed and what use is to be made of it. This school has given considerable study as to the use of spun Rayon. The possibility for the use of spun Rayon (staple fiber) is so varied that the textile industry is learning to appreciate its full value. Careful grading of the Rayon waste is making spun Rayon an important fibre. The English textile trade have developed spun Rayon more extensively than any other country.

New York University has recently announced classes for the study and investigation of Rayon. Other Universities, technical schools, Rayon producers and Rayon fabric manufacturers are installing up-to-date equipment and laboratories for analyzing, testing and applying Rayon in every direction. While these laboratories have no direct influence in improving the quality of the Rayon yarn yet their constructive work with manufacturers of Rayon fabrics reveals the best ways to use the yarn and what standards should be looked for. These are all educational steps which are hardly paralleled in any other industry, which leads one to come to the conclusion that Rayon is a stabilizer for raw silk, wool and cotton; that

it has a large field and that its use is as yet limited and small compared to the immense adaptation it can ultimately be put to.

Following is a chronological table giving the principal events which have contributed to the growth and development of the Rayon industry:

1644—Dr. Robert Hooke, British scientist, experimented and then made the epochal statement that "silk equal to if not better than that produced by the silkworm" will be produced by mechanical means.

1734—René A. F. Réaumur, French scientist, pointed out the possibility of producing artificial fibers along the principle shown by the silk worm and the spiders.

1740—Bon produced filaments from spiders. M. C. F. Cross states that Bon made "quite a notable discovery of an imitation silk."

1740—F. G. Keller, of Saxony, invented the process of making wood pulp mechanically.

1742—Louis Schwabe exhibited a machine in Manchester, for making artificial threads, a forerunner of the present-day spinning machine.

1844—John Mercer experimenting as to actions of caustic soda on textile fibers.

1855—George Audemars, from Lausanne, Switzerland, took out (in England) the oldest known patent for an artificially produced, silk-like fiber, made of collodium and rubber (Nitro-Cellulose).

1856—Sir Joseph Wilson Swan established a plant for the production of nitrocellulose at Newcastle.

1857—E. J. Hughes, England, patented a glass-like fiber composed of starch, glue, fats, tannin, etc.

1862—Ozanium, in an article published in France, made the first known mention of spinnerets consisting of small holes through which the plastic mass is forced to form a filament.

1869—Schützenberger and Naudin prepared for the first time cellulose-acetate.

1877—Sir Joseph Swan, assisted by Charles H. Stern, laid the foundation of the first successful artificial silk plant

through their study of production of light by the incandescences of carbon in a vacuum.

1878—Count Chardonnet starts his investigations and experiments of cellulose at the École Polytechnique.

1878—Franchimont develops the cellulose acetate preparation of Naudin.

1880—Cross and Bevan start their constructive line of investigation of cellulose.

1883—Sir Joseph Wilson Swan in Bromley, England, invented a fiber by dissolving nitrocellulose in acetic acid.

1884—Count Hilaire de Chardonnet, of Besançon, France, took out his first patent on the first commercially successful Rayon filament; he also patented machinery in which many principles adhered to at present are incorporated.

1885—Sir J. W. Swan, England, exhibited what was perhaps the first fabric woven from what was then called artificial silk.

1888—Chardonnet patented a process for the partial denitration of his fiber.

1889—At the Paris Exposition held that year Chardonnet introduced his process to the public.

1889—Dr. Franz Lehner, at Augsburg, Germany, made this fiber from silk waste. He also patented a method of stretching partly dried filaments in order to obtain finer fibers.

1890—Dr. Franz Lehner, at Zurich, Switzerland, developed the principle of continuous spinning of the fiber.

1890—Louis Henri Despaisses in France, patented the first process for making Rayon from cellulose dissolved in ammoniacal copper oxide.

1890—Count Chardonnet built an experimental laboratory at Rue Roussin, Paris, considered as the first artificial silk mill.

1890—Dr. Lehner conducts experiments of Count Chardonnet's method at his Zurich plant (see p. 194, "Revue Industrielle" of 1890).

1890—The owners of Wardle and Davenport, Leek, Messrs. W. H. Rider, G. Davenport and F. Davenport, founded and financed the Tubize Company through negotiations with Count Chardonnet and Count Baudry d'Asson who became managing director.

1892—Charles Frederick Cross, Edward John Bevan and Clayton Beadle, in London, invented the so-called Viscose process.

1893—Denitration process was greatly improved in France.

1893—The Viscose Syndicate Ltd. organized to develop the Cross and Bevan process, the European patents being sold to the Continentale Viscose G. m. b. H.

1894—C. F. Cross, England, patented the first acetate of cellulose process. This was the original form of Celanese.

1894—Count Hilaire de Chardonnet patented a spinneret designed especially for his fibre.

1894—The American Viscose Company, of Boston, acquires the Cross, Bevan and Beadle process.

1895—C. H. Stern and C. Topham commenced investigations on spinning viscose for the Zurich Incandescent Lamp Company.

1895—The Zurich Incandescent Lamp Company forms the Viscose Spinning Syndicate with capital of \$20,000. Laboratory at Kew.

1895—Chardonnet Rayon (nitro-cellulose) market price per pound 10s. 11d.

1895—Dr. Arthur D. Little of Boston, Mass. (U. S. A.) obtains United States patent No. 532468 for cellulose-acetate filament.

1897—Dr. Pauly obtains French patent No. 272718 for dissolving cellulose in ammoniacal solution of copper oxide.

1897—Silbermann, in "Die Seide," discusses the strength of Rayon.

1897—Wm. Bennett, at Salford Technical School, investigates the dyeing of Rayon.

1898—William Porter Dreaper and Harry Kneebone Tompkins, in England, took out the first patent for dissolving cellulose in chloride of zinc or some other zinc salts.

1898—Chardonnet placed on the market a vastly improved Rayon fiber, denitrated and given greater affinity for dyestuffs and rendered less inflammable.

1899—Dr. Emil Bronnert, in Alsace, improved the Dreaper and Tompkins process of 1898 by first dehydrating the cellulose.

1899—Dr. Max Fremery and John Urban, in Germany, invented processes for treating cellulose before it is dissolved in ammoniacal copper oxide.

1899—Adam Millar, Glasgow, patented the first so-called artificial tulle lace, using a solution of gelatine, rubber, etc., as base.

1899—Count Chardonnet awarded first prize for artificial silk.

1899—Charles H. Stern obtains patent for making cellulose filament.

1900—Dr. Emil Bronnert, of Alsace, and Dr. Max Fremery and John Urban, of Aachen, Germany, invented processes for dissolving cellulose in ammoniacal copper carbonate.

1900—Charles F. Topham, London, patented a machine for winding cellulose filaments into cakes, by means of the centrifugal spinning box or pot.

1900—The Vereinigte Kunstseidefabriken A. G., Frankfort on the Main, produced imitation horsehair from cellulose solution.

1900—The Glanzstoffabriken A. G., in Elberfeld, Germany, developed the first commercially successful machine for spinning filaments continuously.

1900—Paris Exhibitions. A convincing display of Rayon goods was arranged for by Count Chardonnet; as a result of which the Société Française de la Viscose was formed.

1901—Dr. Edmund Thiele, Barmen, Germany, invented an improved process for drawing filaments into finer fibers.

1902—J. Stoerk, Brussels, finds that Rayon can be spun when dry best if its water content is from 12 to 20 per cent.

1903—Prince Guido Henckel von Donnersmarck, Silesia, uses viscose base treated with metallic and ammoniacal salts to avoid stickiness in fibre.

1903—Prince Guido Henckel von Donnersmarck developed process on commercial scale for coating cotton yarn with rayon.

1903—Lederer obtained patent on process for producing threads by squeezing cellulose-acetate solution dissolved in acetic acid into alcohol.

1904—The first solvent recovery process for nitro-cellulose manufacture was patented by J. M. A. Denis, in Rheims, France.

1904—Société Française de la Viscose obtains patent on a revolving spinneret plate in order to give twist to Rayon fibers.

1904—J. M. E. Dervin, France, obtains patent for recovering alcohol and ether fumes from air.

1904—Courtaulds purchase Laboratory Viscose spinning unit of the Zurich Lamp Company of Kew.

1905—Rudolf Linkemeyer, Brussels, patented a hollow revolving drum inside of which the hardened fiber is coiled instead of being wound on a cylinder.

1905—Courtaulds moved the Viscose Spinning plant from Kew to Coventry and started manufacturing on a commercial scale.

1905—Glanzstoff took over British patent for the production of "Sirins," an artificial hair-process.

1905—Miles succeeds in producing a cellulose-acetate soluble in a cheaper solvent.

1906—The Vereinigte Glanzstoffabriken A. G., Elberfeld, Germany, patented machinery for the continuous spinning, washing, drying, winding and twisting of the filaments without interruption between these processes.

1907—The Compagnie de la Soie de Beaulieu, in France, patented a process for denitrating yarn before the filaments have become hard.

1907—The J. P. Bemberg A. G., in Barmen-Rittershausen, Germany, patented Rayon making machinery by agitating the coagulating liquids, claiming to avoid breakage.

1907—Prince Guido Henckel von Donnersmarck, in Sydow-saue, Germany, uses cellulose acetate as a base for Rayon yarn.

1907—Marius Ratignier, in Villeurbanne, France, patented an improved process for so-called artificial tulle or lace.

1908—Bernard Loewe in Paris, invented a new spinning process in which a large space is provided for between the spinnerets and bobbins, allowing the filament to dry in the air.

1908—The Vereinigte Kunstseidefabriken A. G., in Kelsterbach a.M., Germany, invented an imitation horsehair (crinol) using cuprous chloride.

1908—The Vereinigte Glanzstoffabriken, in Elberfeld, Germany, injected viscose into a mineral acid coagulating bath.

1908—Samuel Courtauld & Co., Ltd., London, patented a spinning machine with hollow spindles equipped at one end with spinnerets.

1908—United Cellulose Silk Spinnery Co., Ltd. built at Yarmouth. Sold in 1912 to Brysilka.

1908—First Italian Chardonnet Rayon Company built at Padova.

1909—The Guido Donnersmarcksche Kunstseide und Acetatwerke use formic acid as a solvent for the first time.

1910—The first industrial plant for the manufacture of Rayon (according to the Viscose process) in the United States was started at Marcus Hook, Pa.

1910—Glanzstoff obtains patent for redissolving Rayon waste.

1910—Rudolf Mewes, of Berlin, develops process for producing hollow filaments.

1910—Paul Girard, Paris, obtains French patent 438131 for making staple fiber.

1911—Paul Gerard, France, produced straw-like tubes from cellulose solution.

1911—E. de Haen, near Hamburg, prepares the rayon cellulose from straw.

1911—H. Dreyfus obtains French patent 412264 on acetone soluble acetate, as a result of which the British Cellulose and Chemical Mfg. Co. of Spondon, Derbyshire, was formed with Government co-operation. It is now the British Celanese Ltd.

1911—F. & G. Mitchell obtain British patent 29030 for cutting short lengths of Rayon "staple fiber."

1912—Rayon was used in quantities for hosiery.

1912—Peter Spence & Sons, Ltd., in Manchester, England, patented a metallic finish produced by precipitating copper on the surface of the fibre.

1913—Samuel Courtauld & Co., Ltd., England, patented a process for oxydizing nitrate of cellulose previous to its conversion into Viscose.

1913—Joseph Foltzer obtains Swiss patent 69514 for making tulle lace direct from cellulose at the rate of 2178 yards per day.

1916—The first knitted fabric for outerwear, made exclusively from Rayon, appeared on the market.

1917—Snia Viscosa of Italy founded.

1919—First experiments on a small scale in this country to use Rayon in underwear.

1923—Arnold H. Hard proposes the combination of acetate and cotton-woven fabrics for rubber-proofed coats.

1924—The term "Rayon" in place of artificial silk or similar

names is generally accepted by the trade in the United States and England.

1925—The greatest year of the industry's development. Many new plants established.

1926—Depression in Rayon demand and price reduction.

1926—A general improvement in quality of Rayon.

1926—Bemberg, of Germany, erects their first cupra-ammonium Rayon producing unit in the United States at Johnson City, Tennessee.

1927—Glanzstoff commence plans to erect their first American viscose unit at Elizabethton, Tennessee.

1928—Enka, of Holland, commences its first American viscose unit at Asheville, North Carolina.

1928—The American Chatillon Corporation commences its first American unit at Rome, Ga.

1928—Again a great boom in the Rayon industry, seemingly of a permanent nature due to its greater demand for mixtures in the textile industry.

Hitherto in the production of Rayon the term "spin" or "spinning" has been used to denote the ejection of the cellulose solution through very fine orifices called spinnerets in order to make the Rayon filaments. The use of these terms "spin" or "spinning" are incorrect and do not define the operation. What actually occurs is that a cellulose solution is ejected by pump pressure through these orifices but since these incorrect terms have become general, the Author finds it necessary solution through very fine orifices called spinnerets in order to avoid confusion through the elimination and renaming of these terms.

CHAPTER III

THE PRODUCTION OF RAYON

THE production of Rayon throughout the world and more especially in the United States, Italy, and to a lesser degree, Japan, has been phenomenal. The universal demand for it in so many different lines of the textile and other industries

TABLE I. RAYON PRODUCTION BY YEARS AND COUNTRIES,
MILLION POUNDS

Country	1913*	1922*	1923*	1924†	1925†	1926†	1927†	1928†
United States....	1.6	24.4	35.4	38.7	52.2	62.6	75.0	97.9
Italy.....		6.3	10.1	18.5	30.0	35.0	37.0	45.0
Great Britain....	11.5	15.3	17.0	23.9	28.0	25.5	36.0	52.0
Germany.....	7.8	12.6	16.0	23.7	27.1	26.0	35.5	41.0
France.....	3.1	6.3	7.7	12.3	14.4	17.5	19.8	30.0
Holland.....		2.5	3.9	3.4	4.4	13.5	16.5	16.5
Belgium.....	3.0	6.3	8.0	8.9	11.1	13.1	13.5	15.0
Switzerland.....	0.3	1.9	3.7	4.0	5.5	8.0	10.3	12.0
Japan.....		0.25	0.2	1.2	1.4	5.5	8.0	12.0
Austria.....	1.5	1.6	2.5	2.6	3.5	3.5	3.5	4.5
Czecho Slovakia..		0.6	2.0	1.3	2.0	2.8	3.5	3.5
Poland.....		0.9	1.2	1.5	2.2	2.0	4.0	7.5
Canada.....						2.2	2.5	4.0
South America....						2.2	0.35	0.9
Spain.....				0.2	0.2	0.3	1.0	2.5
Others.....		1.95	1.1	1.0	1.0	1.38	1.75	2.0
Total, World...	28.8	80.9	108.8	141.2	183.0	219.1	268.2	346.3

* Tariff Information Survey.

† Textile World.

has brought about a condition of stability and quality in its production rarely obtained in so short a period of time in any industry of its present proportions.

In 1913 the world production of Rayon was 29,000,000

TABLE 2.—SHOWING NUMBER OF COMPANIES AND NUMBER OF FACTORIES IN OPERATION AND UNDER CONSTRUCTION BY COUNTRIES

Country	Num-ber of Com-panies	Num-ber of Fac-tories	Process of Manufacture			
			Viscose	Nitro-Cellulose	Cupra-Ammonia	Acetate
United States.....	17	28	20	I	3	4
Italy.....	12	24	23	.....	I	
Great Britain.....	15	20	14	.....	I	5
Germany.....	11	29	22*	I	5	I
France.....	36	38	31	I	I	5
Holland.....	2	3	3			
Belgium.....	9	11	9	I	.....	I
Switzerland.....	5	5	5			
Japan.....	13	16	16			
Austria.....	I	I	I			
Czecho-Slovakia.....	5	6	6			
Poland.....	3	3	3†			
Canada.....	2	2	I	.....	.....	I
Brazil.....	I	I	I			
Spain.....	3	3	3			
Hungary.....	3	I	I			
Sweden.....	I	I	I			
Russia.....	2‡	2	2			
Greece.....	I	I	I§			
Ireland.....	I	I	I			
Norway.....	I	I	I			
Total.....	144	197	165	4	11	17

* Two plants produce by Cupra-ammonium method also.

† One plant produces by Nitro-cellulose process also.

‡ Factories to be erected by the U. S. R. R. not included.

§ Produces also by Acetate process.

pounds and in 1927 it had reached the colossal amount of 269,000,000 pounds or over nine times as much in 15 years,

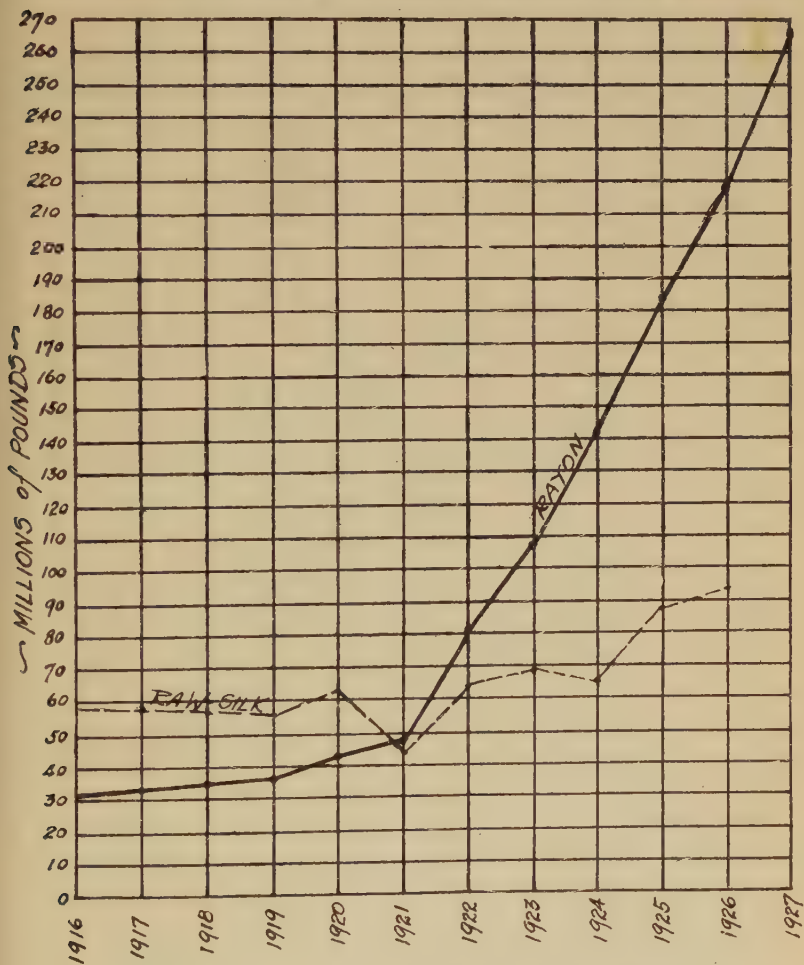


CHART I. Relative World Production of Raw Silk and Rayon from 1916 to 1924.

an average of approximately 17.5 per cent annual increase. In this tremendous growth the United States has been the

leader both in quantity and quality and today is the largest producer, consumer and importer of Rayon in the world. Table 1 shows the production figures by years and countries.

Rapid as has been the increase in demand for Rayon throughout the world, there is no sign of any lessening in this ever-increasing demand, as clearly evidenced by the new fac-

TABLE 3.—RELATIVE WORLD PRODUCTION OF RAW SILK AND RAYON SINCE 1916

	Million Pounds											
	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927
Raw silk *.....	58.5	59.8	59.0	56.3	61.0	46.5	64.6	60.8	66.0	88.0	92.0	
Rayon.....	31.2	33.0	34.6	36.4	41.2	47.8	80.9	108.8	141.2	183.0	219.1	265.9

* These figures are exclusive of local consumption in the producing countries.

TABLE 3A.—COMPARISON OF WORLD PRODUCTION OF FOUR PRINCIPAL FIBRES FOR YEAR 1926

Fibre	Million Pounds	Per Cent	Fibre	Million Pounds	Per Cent
Cotton....	10,000,000,000	80.87	Rayon....	219,000,000	1.26
Wool.....	3,000,000,000	17.33	Silk.....	92,000,000	0.54

tories under construction and consideration, and by the large expansion programs to increase production of the established Rayon companies both here and abroad. In 1927 there were about 134 Rayon companies in operation, controlling some 165 plants either operating or under construction, which were distributed by countries and processes as shown in Table 2.

In the above Table 2 no account has been taken of those companies in the organization stage only, many of which will soon develop into producing concerns.

RELATIVE WORLD PRODUCTION

Less than a decade ago the production of Rayon in comparison with other textiles was relatively negligible but within the last five years it has exceeded that of silk. When compared

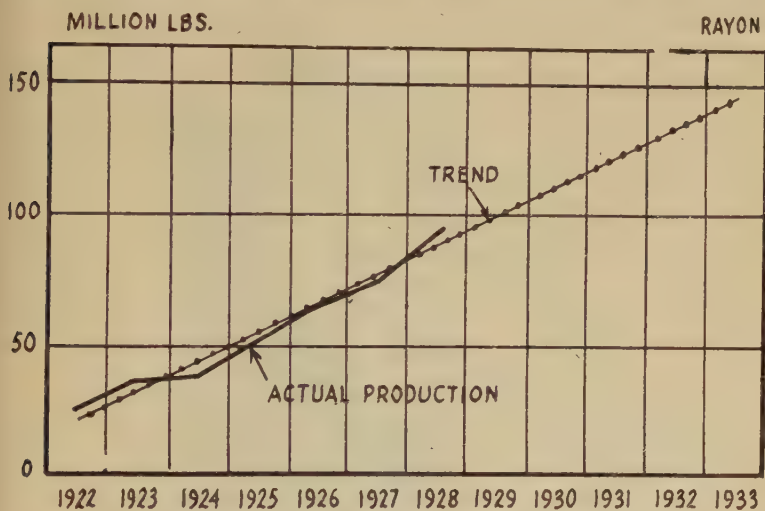


CHART 2. Comparison Actual U.S. Production to Trend Curve.

with cotton and wool, however, the production of Rayon is still insignificant and must grow to many times its present size before it can in any way affect, if ever, the production of either of them. The fallacy often put forward that Rayon would take the place of silk is exposed by referring to Table 3 and to its graphical expression in Chart 1 which show the relative world production of Rayon and silk and clearly bring out the fact that the production of silk is steadily increasing with that of Rayon.

THE RAYON INDUSTRY

PRODUCTION BY COUNTRIES

UNITED STATES

The United States did not enter the field of Rayon production until the year 1910. By the year 1913 it ranked fifth

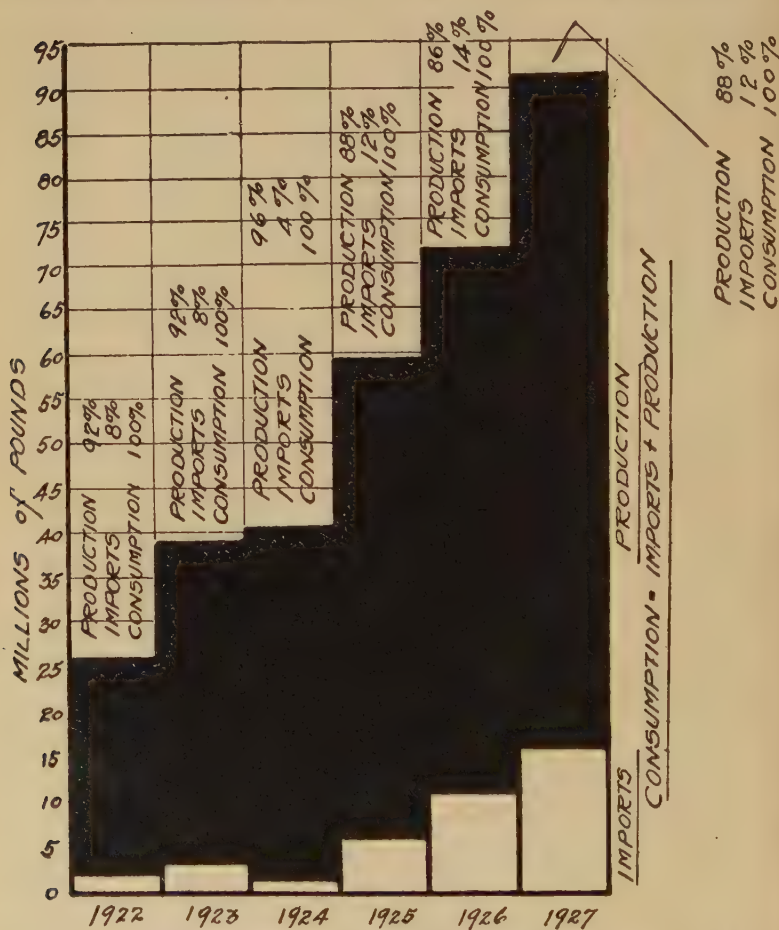


CHART 3. United States Production, Imports, and Consumption of Rayon.

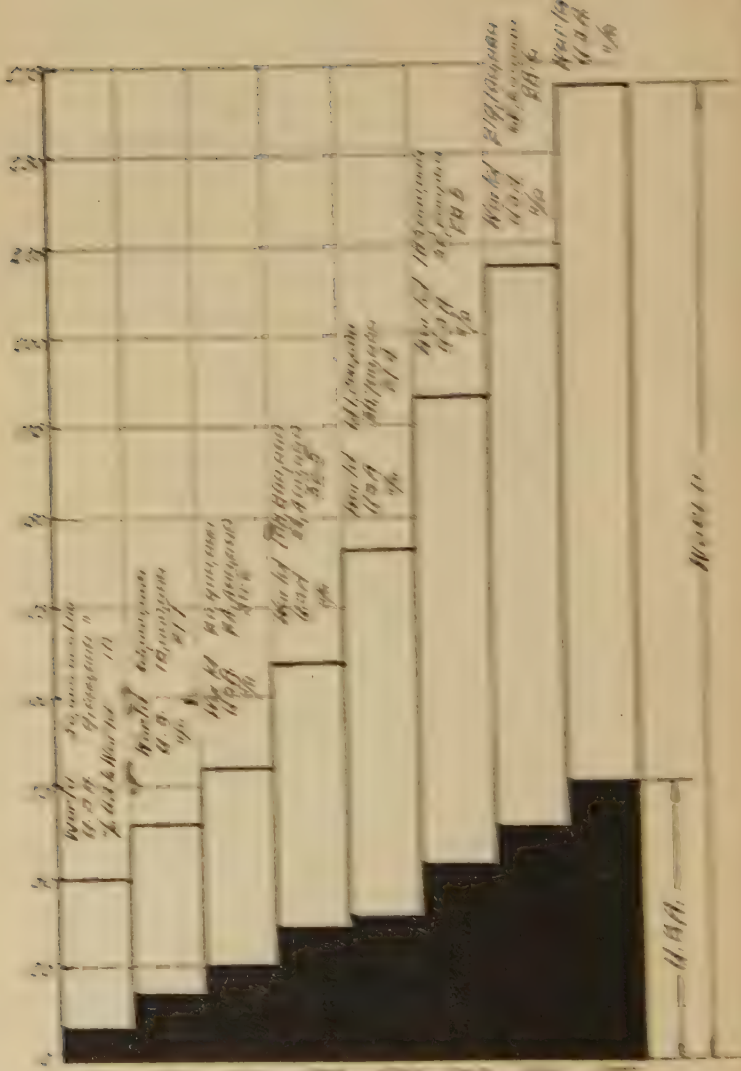
among the nations producers and from then on it forged ahead to the leadership. During 1927 it produced 75,000,000 pounds more than twice as much as Italy, its nearest competitor in production, and approximately 28 per cent of the world's production. The average yearly increase since 1922 has been approximately 11,000,000 pounds, or 20 per cent.

Chart 2, an interesting chart prepared by the Department of Commerce, shows how closely the actual domestic production of Rayon has hitherto conformed to the estimated trend curve, but from the production figures available during the early part of 1928 the indications are that production will be considerably in advance of the estimated trend.

TABLE 4.—UNITED STATES CONSUMPTION, PRODUCTION AND IMPORTS

Calendar Year	Thousand Pounds		
	Approximate Consumption	Approximate Domestic Production	Imports for Consumption
1911	2,100	300	1,800
1912	2,600	1,100	1,500
1913	3,900	1,600	2,300
1914	4,900	2,400	2,500
1915	7,100	4,100	3,000
1916	6,700	5,700	1,000
1917	7,200	6,700	500
1918	5,900	5,800	100
1919	9,300	8,200	1,100
1920	11,700	10,200	1,500
1921	18,300	15,000	3,300
1922	26,100	24,000	2,100
1923	38,500	35,400	3,100
1924	40,400	38,700	1,700
1925	52,200	52,200	7,000
1926	72,700	62,600	10,100
1927	91,300	75,000	16,300

Chart 1. Comparison of Total Solid Production in Russia in 1913



1. All Russia
2. European Russia
3. Siberia
4. Far East
5. Caucasus
6. Central Asia
7. Turkestan
8. Trans-Caspian
9. Trans-Arctic
10. Trans-Baikal
11. Trans-Volga
12. Trans-Ural
13. Trans-Siberian
14. Trans-Caucasian
15. Trans-Asian
16. Trans-Eurasian
17. Trans-Oceanic
18. Trans-Continental
19. Trans-Global
20. Trans-Universal

The United States being the largest consumer of Rayon yarns it was inevitable that it should become the largest producer and notwithstanding the rapid growth of the industry the supply has never reached the demand. On the contrary, the quantity of imported Rayon increases yearly. Table 4 and Chart 3 give the production, imports and consumption of Rayon in the United States and Chart 4 shows the comparison of United States production to world production.

Figures obtained for production in the United States during the first five months of 1928, indicated a production for that year of over 100,000,000 pounds. From the enormous consumption of Rayon yarns brought about by the greater demand for it in the established channels for its use, and through the many new channels, it may be predicted that the annual imports will reach 25,000,000 pounds.

From the above it will be seen that supply and demand are further apart than ever and the prospects of

TABLE 5.—THE COMPANIES IN THE UNITED STATES RESPONSIBLE FOR THE LARGE PRODUCTION OF RAYON AND THE QUANTITIES PRODUCED BY EACH.

Company	Pounds				
	1924	1925	1926	1927	1928
The Viscose Co.....	28,000,000	35,000,000	37,000,000	41,000,000	54,000,000
DuPont Rayon Co.....	4,000,000	6,761,560	10,900,000	15,100,000	18,161,000
Tubize Artificial Silk Co.....	4,250,000	5,200,000	7,000,000	7,500,000	8,500,000
Industrial Rayon Corp.....	2,000,000	2,250,000	3,400,000	3,450,000	4,250,000
Celanese Corp. of Amer.....		1,500,000	2,500,000	3,500,000	5,000,000
Belamose Corp.....		675,000	875,000	1,400,000	1,650,000
Acme Rayon Corp.....		322,665	400,000	500,000	740,250
Skenandoa Rayon Corp.....				1,000,000	1,150,000
Delaware Rayon Corp.....				500,000	1,500,000
Amer. Bemberg Corp.....				350,000	2,100,000
Amer. Glanzstoff Corp.....					350,000
Other firms.....	600,000	500,000	500,000	750,000	500,000
Total.....	38,850,000	52,209,225	62,575,000	75,050,000	97,901,250

this country exporting Rayon are still quite remote. The nations of the Orient, of the Antipodes and South America are rapidly becoming large consumers of Rayon and these markets should logically be supplied from the United States. Such a condition, therefore, shows the necessity of far more rapid expansion in production than has been the case heretofore and it is safe to predict that within the next few years at least ten more companies will be producing Rayon. Most of these companies also will be backed by American capital, for the investing public is not going to miss the opportunity of obtaining some of the large dividends which have been and will continue to be paid for many years to come.

In Chapter VII, on "Trade Economics" will be found the source of imported Rayon yarns.

A brief description of the United States Rayon producing companies, listed in Table 5, follows:

The Viscose Company

Headquarters	New York City
Production started	1911
Factories	(1) Marcus Hook, Pa.
	(2) Lewistown, Pa.
	(3) Roanoke, Va.
	(4) Parkersburg, W. Va.
Process	Viscose and Acetate
Output, 1928	54,000,000 pounds

This company is a branch of Courtaulds, Ltd. of England. It is the largest company in the United States and produced approximately 55 per cent of the United States production in 1927 and over 15 per cent of the world's production for the same year. It operates a cotton linters pulp plant at Nitro, W. Va. Both wood pulp and cotton linters are used as the basic raw materials. The plant for the production of

Rayon by the acetate process was in course of erection in the early part of 1928.

Mr. S. A. Salvage, President of the Company, in a letter of May, 1928, to the author regarding the operations of his company, stated that the capacity of the Buffalo and pounds of Viscose yarn per year and in a year would be 66,000,000 pounds. In addition, another plant is being erected to produce 3,500,000 pounds of acetate yarn per year.

Du Pont Rayon Co.

Headquarters	Buffalo, N. Y.
Factories	(1) Buffalo, N. Y.
	(2) Old Hickory, Tenn.
Process	Viscose and Acetate
Denier	80 to 450
Output, 1928	18,161,000 pounds

This company was organized in 1920 as the DuPont Fiber-silk Co., a combination of E. I. DuPont de Nemours & Co. and the Comptoir des Textiles Artificiels of France.

Mr. L. A. Yerkes, President of the Company in a letter of May, 1928, to the author regarding the operations of his company, states that the present capacity of the Buffalo and Old Hickory plants is 18,000,000 pounds per annum. An additional unit which will start operations in July, 1928, at the Old Hickory plant will increase the capacity to 22,000,000 pounds per annum. A new plant has just been started at Richmond, Va., which will be ready in 1929 and will further increase capacity to 26,000,000 pounds per annum. In June, 1928, work was started on the erection of a plant for the manufacture of cellulose acetate Rayon, the first unit of which will have a capacity of 3,000,000 to 4,000,000 pounds per annum. This plant is located at Waynesboro, Virginia.

THE RAYON INDUSTRY

Tubize Artificial Silk Company of America

Headquarters	Philadelphia
Factory	Hopewell, Va.
Process	Nitro-cellulose (Chardon- net)
Basic raw material	Cotton Linters
Output, 1928	8,500,000 pounds

This company was organized in 1920 as an outgrowth of the Fabrique de Soie Artificielle de Tubize of Belgium.

Industrial Rayon Corporation

Headquarters and Factory.	Cleveland, Ohio
Process	Viscose
Denier	150 and 300
Output, 1928	4,250,000 pounds

This company is the successor of the Industrial Fibre Corporation of America which was organized in 1920 as the result of a merger of the American Boovisk Company with the Snia Viscosa of Italy.

Mr. Hiram S. Rivitz, President of the Corporation, in a letter of May, 1928, regarding the operations of his company stated that the capacity of the Cleveland factory is about 4,500,000 pounds per annum in 150 denier 24 filament, and 300 denier 44 filament in skeins and in cones. They are about to erect an additional plant in two units at Covington, Va., of an approximate capacity of 5,500,000 pounds per annum, producing a limited quantity of 300 and 150 denier and possibly a greater variety of finer deniers and more filaments.

Celanese Corporation of America

Headquarters	New York City
Factory	Amcelle, Md.
Process	Acetate
Output, 1928	5,000,000 pounds

This company is the successor to the American Cellulose and Chemical Manufacturing Company, Limited, which was an outgrowth of the British Celanese Limited. Production was started in a small way on January 1st, 1925. This company also manufactures non-inflammable celluloid, non-inflammable films, lacquers and varnishes. Additional funds have been provided for further extensions to increase capacity which will be in operation in 1929.

Belamose Corporation

Headquarters and Factory. Rocky Hill, Conn.

ProcessViscose

Output, 19281,650,000 pounds

This company represents American and Belgium interests. It started commercial production in January, 1925. It is reported that extensive additions are being made to increase capacity.

The Delaware Rayon Corporation

Headquarters and Factory. New Castle, Ind.

ProcessViscose

Output, 19281,500,000 pounds

This company purchased the former shell-loading plant of the Bethlehem Steel Company at New Castle, Delaware. Production started early in 1927. It is reported that plans are perfected to increase considerably the capacity of the factory with another plant erected at New Bedford, Massachusetts, known as the New Bedford Rayon Company.

Acme Rayon Corporation

Established1920

Headquarters and Factory. Cleveland, Ohio

ProcessViscose

Denier150 and 300

Output, 1928740,250 pounds

This company, although established in 1920, did not produce commercially until 1924. It is reported that preparations are under way to take care of considerably greater production.

American Bemberg Corporation

Headquarters	New York City
Factory	Johnson City, Tenn.
Process	Cupra-ammonium
Denier	All
Output, 1928	2,100,000 pounds
Capacity	2,500,000 pounds per year

This company was established in 1925 as the result of an arrangement between J. P. Bemberg & Co. of Barmen, Germany and the Vereinigte Glanzstoff-Fabriken A.-G. of Elberfeld. The factory was completed in October, 1927, and production started immediately thereafter. Work has already been started on a second unit of the present factory which is expected to be in operation by the end of 1928. The second unit will provide a total capacity of 5,500,000 pounds per annum.

The Amoskeag Manufacturing Company

Factory	Manchester, N. H.
Process	Viscose
Capacity	1,500,000 pounds per year

This company is one of the largest cotton spinning companies in the world and operates its own Rayon factory applying the entire product to its own use.

Skenandoa Rayon Corporation

Headquarters and Factory.	Utica, N. Y.
Process	Viscose
Output, 1928	1,150,000 pounds

This company acquired the properties of the Skenandoa Cotton Co., which company has moved its equipment to Lafayette, Alabama. The entire output of the Rayon company is used by the cotton company. Arrangement has been made with the Strasbourg interests of France for technical advice and aid. Expansion program now under way provides for a capacity of 3,000,000 pounds per annum.

Rosland Corporation

The Rosland Corporation has a plant at Paterson, N. J., and commercial production started early in 1928. Rayon yarn is produced by the cupra-ammonium process.

No definite information can be obtained regarding the operations of this company but it is believed that production for 1928 will be very small.

American Glanzstoff Corporation

The American Glanzstoff Corporation is a branch of the Vereinigte Glanzstoff-Fabriken Akt. Ges. of Elberfeld, Germany and was organized in May, 1927. The plant in Elizabethton, Tenn., began producing in 1928. Rayon is produced by the Viscose method and the present installation of machinery and equipment provides for a capacity of 5,000,000 pounds per annum.

Mr. Beveridge C. Dunlop, Vice-President of the Company, in a letter under date of May 9th, 1928, to the author regarding the manufacturing operations of his company, said that the plant in Elizabethton, Tennessee, will, when completed, have an approximate daily production of 14,000 pounds of Viscose yarn. At the present time no further enlargement is contemplated.

Furness Corporation

The Furness Corporation was incorporated in Camden, N. J., to produce super-ammonium Rayon yarn by a process developed by William H. Furness. At the present time production is on a laboratory scale only.

Rayon Plant at Burlington, North Carolina

A plant has been built and machinery and equipment installed in a plant at Burlington, North Carolina, to produce Rayon yarn by the Viscose process under the direction of Albert M. Johnson, President of the National Life Insurance Company of Chicago, Illinois. The name of the new company is the A. M. Johnson Rayon Mills, Inc.

CANADA

Canada being the chief producing country in the American continent for one of the bases of Rayon yarn—sulphite wood-pulp—is the logical place to operate several Rayon plants, especially in the west where there are none at present. Canada should be operating a number of plants, not alone for domestic use but for export to the markets of South America and the Orient and even to its neighbor—the United States. The plants could be located where the cost of preparing the raw material for shipment and the shipping charges could be eliminated.

It is only within the last three years that Canada has been producing her own Rayon yarn and there are only two plants in operation. These two are:

- (1) Canadian Celanese, Limited
- (2) Courtaulds, Limited.

Canadian Celanese, Limited

Canadian Celanese, Limited, is a branch of British Celanese, Limited, and during 1927 completed the first units of its plant and started manufacturing operations. The plant is located at Drummondville, Quebec, and produces Rayon yarn by the cellulose acetate process. The capacity of the plant for which the present plans provide is approximately 1,500,000 pounds per year. In addition to making Rayon yarn the Company operates 55 looms on fabrics.

Courtaulds, Limited

Courtaulds, Ltd. is a branch of Courtaulds, Limited, England. It started producing Rayon yarn by the Viscose process in 1927. The plant is at Cornwall, Ontario on the St. Lawrence River. Capacity of the plant is 2,500,000 pounds per annum.

BRAZIL

There is only one Rayon producing company in South America and that is the Industrias Reunidas F. Materazzo in Brazil.

TABLE 7.—BRAZILIAN PRODUCTION, IN POUNDS

Year	Production	Year	Production
1927	350,000	1928	880,000

Industrias Reunidas F. Matarazzo

Headquarters San Paulo
 Process San Caetano
 Factory Viscose
 Capital \$3,200,000

Large quantities of Rayon yarn are imported into Brazil, the amount in 1927 being 5,000,000 pounds.

EUROPEAN PRODUCTION

The manufacture of Rayon yarn originated in Europe and the industry had reached considerable proportions before its manufacture started in other countries. In 1927 the combined production of all European countries was 182,050,000 pounds or 68 per cent of the total world production.

ITALY

Italy was the largest producer of Rayon in Europe and the second largest in the world until 1928 when it was surpassed

TABLE 8.—ITALIAN PRODUCTION

Year	Production, Pounds	Year	Production, Pounds
1922	6,300,000	1925	30,000,000
1923	10,100,000	1926	35,000,000
1924	18,500,000	1927	37,000,000
		1928	45,000,000

by Great Britain. Italy is the largest exporter of Rayon in the world. Of her total production in 1927 of 37,000,000 pounds it exported 21,000,000 in addition to 5,000,000 pounds from old stocks.

Rayon was first produced in Italy in 1908 by the Char-donnet or nitro-cellulose process but this particular operation was soon abandoned. Active production on a commercial basis may be said to date from about 1920, when the Snia Viscosa acquired plants at Venaria Reale, Pavia and Caesano Maderno, which had been operating before then on a small scale.

The exportation of Rayon from Italy is noteworthy be-

cause of its tremendous growth and the way in which a shift in markets was accomplished when the necessity arose.

The outlook for the Rayon industry in Italy is very bright. Professor Mortora, an authority on industrial and commercial undertakings, forecasted the production of Rayon in 1928 in excess of 60,000,000 pounds.

In Table 8 is shown the production. Exports and imports of Rayon and the distribution by countries of Italian exports are given in the Chapter VII on Trade Economics.

SOCIETA NATIONALE INDUSTRIA APPLICAZIONE
VISCOSA

(Snia viscosa)

Headquarters	Turin
Factories (Rayon yarn) ..	(1) Turin (Abbadia di Stura)
	(2) Pavia
	(3) Venaria Reale (Unione Italiana Fabbriche Viscosa)*
	(4) Cesana Maderno (Societa Italiana Seta Artificiale)*
Factories ("Sniafil")	Turin (Abbadia di Stura)
	Altessano
Factories (Processing) ..	Turin (Via Frejus 21)
	Altessano
Factories (Raw Materials)	Rumianea
	Venaria Reale
	Ferrara Padua
	Reggio Emilia
Factory (Machinery)	Turin (Via Frejus 21)
Process	Viscose
Denier	90-500
Capital	1,000,000,000 lire

* Subsidiary companies controlled by Snia Viscosa.

This company is the largest manufacturer of Rayon in Italy and produces more than 50 per cent of the total Italian production.

"Sniafil" is an artificial fiber having the appearance and texture of wool. It is also manufactured in England.

LE SOIE DE CHATILLON

Headquarters	Milan
Factories	(1) Chatillon
	(2) Ivrea
	(3) Vercelli
Process	Viscose
Denier	80-1,000
Output	11,000,000 pounds per annum
Capital	200,000,000 lire

This company manufactures also

- (1) Artificial wool
- (2) Rayon shoppe—"Seres"

SOCIETA GENERAL ITALIANA DELLA VISCOSA

Headquarters	Rome
Factories	(1) Rome
	(2) Padua
	(3) Rieti (Societa "Super-tessile")*
	(4) Naples (Societa Meridionale Seta Artificiale)*
Process	Viscose
Denier	60-300
Capital	340,000,000 lire

* Rayon companies controlled by Societa General.

THE RAYON INDUSTRY

SETA ARTIFICIALE VAREDO

Headquarters	Turin
Factories	(1) Varedo
	(2) Naples
	(3) Ceriano Laghetto (Seta Artificiale Ceriano)*
	(4) Aquila (Seta Artificiale Aquila)*
Process	Viscose
Denier	80-900
Capital	100,000,000 lire

This company also manufactures

- (1) Artificial Horsehair
- (2) Artificial Straw (Visca)

SOCIETA ANONIMA GERLI INDUSTRIA RAYON

Headquarters	Milan
Factory	Casano Milanino
Process	Viscose
Output	4,400 pounds per day
Capital	50,000,000 lire

SETA ARTIFICIALE ITALO-OLANDESA ENKA

Headquarters	Milan
Factory	Pizzighettone
Process	Viscose
Capital	105,000,000 lire

SOCIETA ANONIMA VISCOSA VERCELLESE

Headquarters	Milan
Factory	Palestro
Process	Viscose
Output	4,400 pounds per day
Capital	44,000,000 lire

*Rayon companies controlled by Seta Artificiale Varedo.

THE PRODUCTION OF RAYON

67

SOCIETA ANONIMA ORSI MANGELLI FORLI

Headquarters Milan
Factory Forli
Process Viscose
Capital 6,000,000 lire

SOCIETA ITALIANA SETA BEMBERG

Headquarters Milan
Factory Gozano
Process Cupra-ammonium
Capital 12,000,000 lire

SOCIETA ANONIMA FIBRE TESSILLI ARTIFICIALE

Headquarters Milan
Factory Piacenza
Process Viscose
Capital 750,000 lire

INDUSTRIE CHIMICHE DEL VENETO

Headquarters Milan
Factory Cismon sul Brenta
Process Viscose
Capital 500,000 lire

MANIFATTURA SETA ARTIFICIALE

Established 1924
Headquarters Milan
Factories Casale Monferrato
 Novara
Process Viscose
Denier 40-400
Capital 16,000,000 lire

TABLE 9.—SUMMARY OF RAYON PLANTS IN ITALY FOR 1927

Company	Number of Factories			
	Vis.	C.A.	N.C.	A.
Societa Nazionale Industria Applicazione Viscosa.....	4			
Le Soie de Chatillon.....	3			
Societa General Italiana della Viscosa.....	4			
Seta Artificiale Varedo.....	4			
Societa Anonima Gerli Industria Rayon.....	1			
Seta Artificiale Italo-Olandesa.....	1			
Societa Anonima Viscosa Vercellese.....	1			
Societa Anonima Orsi Mangelli Forli.....				
Societa Italiana Seta Bernberg.....		1		
Societa Anonima Fibre Tessili Artificiale.....	1			
Industria Chimiche del Veneto.....	1			
Manifattura Seta Artificiale.....	2			
Total.....	22	1		

GREAT BRITAIN

The condition of the Rayon industry in Great Britain is a peculiar one in that it has been forced through economic conditions and numerous industrial crises to feel more carefully its way than most other countries. It started out as the largest producer of Rayon yarns, supplying about 40 per cent of the world output until in 1915 it was supplanted as the world's largest producer in the United States. In 1925 the second place was wrested from it by Italy. Since 1925 it has held third place with Germany a close fourth.

From the beginning, the production of Rayon in Great Britain has been practically a monopoly, the firm of Courtaulds, Limited, of Coventry, England, producing about 90 per cent of the total. With the expansion of the smaller com-

panies and the establishment of many new ones, however, the condition is changing and this company will now supply only about 60 per cent of the total.

The demand for Rayon yarn in its many forms both in this country and abroad was so rapid that it was simply a question of turning out the yarn with very little attention given to quality. The consequence was that Rayon, or artificial silk, as it was called until recently, in Europe, fell into bad repute in many quarters with a mistaken conception regarding it prevalent among the general public. On account of the rapid growth of the industry there was always the menace of over-production, for no one in those early days could foresee the many channels which would be provided for its use.

Two very important factors exist in Great Britain, as in all other countries, which have great bearing on the Rayon industry. These were brought about by the Courtaulds-Glanzstoff-Snia Cartel. These factors are, (1) the efforts to improve quality, (2) close watch on the demand for Rayon yarns to prevent over-production.

In the first of these there exist both the desire and facilities for accomplishment as instanced by the large research departments maintained by schools and by the producing companies themselves. As to the second factor, there has been no cause for anxiety because the world supply has not kept pace with the demand.

There are 12 producing companies in Great Britain and 7 either under construction or projected. Rayon is produced by all processes with the exception of the Chardonnet or nitro-cellulose.

In Table 10 are shown production figures for Great Britain by years. The imports, exports, the principal markets and the distribution of Great Britain's Rayon imports are tabulated in Chapter VII on Trade Economics.

BRITISH CELANESE, LIMITED

Headquarters	London
Production started	1920
Factories	(1) Willesden, London N.W. (2) Spondon, near Derby
Process	Acetate
Output (1928)	9,000,000 pounds per year
(Projected)	27,500,000 pounds per year
Denier	45 to 300
Capital	£6,000,000

The British Celanese, Limited, is the second largest Rayon producing company in Great Britain and the largest producer of cellulose acetate Rayon in the world. It manufactures under the Dreyfus patents and controls the American and Canadian Celanese companies.

This company has had a somewhat stirring career both internal and external, the external problems being principally those of lawsuits and infringements of patents.

In addition to the manufacture of acetate yarns there are also produced non-inflammable celluloid and non-inflammable raw film in large quantities.

THE BRITISH ENKA ARTIFICIAL SILK CO., LTD.

Headquarters	London
Production started	1926
Factory	Aintree, Liverpool
Process	Viscose
Output (1928)	1,500,000 pounds per year
(Projected)	5,280,000 pounds per year
Capital	£1,000,000

The British Enka Artificial Silk Co., Ltd., which has the backing of the Dutch Enka Co. of Arnheim, is building a very much larger factory than it is at present operating, and when

THE RAYON INDUSTRY

it is finished, production capacity will be increased to at least three times what it is at present.

WESTERN VISCOSE SILK MILLS, LIMITED

Headquarters	Bristol
Production started	1927
Factory	Bristol
Process	Viscose
Output (1928)	1,300,000 pounds per year
(Projected)	1,540,000 pounds per year
Capital	£400,000

The Western Viscose Silk Mills, Limited, started producing Rayon yarn in the latter part of 1927. The company also operates more than 2,000 spinning spindles. Enlargement is contemplated.

BRITISH ACETATE, LIMITED

Headquarters	Stowmarket, Suffolk
Production started	1925
Factory	Stowmarket
Process	Acetate and Viscose
Output (1928)	Acetate—200,000 pounds per year
	Viscose — 1,300,000 pounds per year
(Projected)	Acetate — 5,500,000 pounds per year
	Viscose — 2,970,000 pounds per year
Capital	£2,700,000

British Acetate, Limited, has recently acquired Bulmer Rayon Company, Limited, and plans are under way for greatly increased production, especially of the acetate yarn.

Bulmer Rayon Co. was organized in 1924 and commenced operations in 1925. Its operations were not successful and reorganization took place in 1928 under the name of British Acetate.

HARLENS (VISCOSE SILK MANUFACTURERS), LIMITED

Headquarters	Golborne Lanes
Production started	1926
Factory	Golborne
Process	Viscose
Output (1928)	1,100,000 pounds per year
(Projected)	2,200,000 pounds per year
Denier	75-85
Capital	£571,300

In 1927 Harlens entered into an agreement with the Branston Artificial Silk Co. whereby, in consideration for financial assistance on the part of the latter company they were to have technical advice from Harlens.

To meet the demand for a yarn with a subdued luster this company produces a special yarn under the trade name of "Matrix" which is well and favorably known.

BRITISH VISADA, LIMITED

Headquarters	Littleborough Lanes
Production started	1927
Factory	Littleborough
Process	Viscose
Output (1928)	880,000 pounds per year
(Projected)	1,320,000 pounds per year
Denier	150 average
Capital	£360,000

THE RAYON INDUSTRY

KEMIL, LIMITED

Established	1923
Headquarters	Manchester
Factory	Flettoa, Peterborough
Output (1928)	Viscose (Hollow Filament)
Output	770,000 pounds per year
Denier	80-200

This company produces a hollow filament Viscose yarn known as "Celta." There is a good market for this yarn because of its soft texture and appearance.

NUERA ART-SILK CO., LIMITED

Headquarters	Sutton Lanes
Production started	1926
Factory	Sutton
Process	Viscose
Output (1928)	660,000 pounds per year
Capital	£630,000

The Nuera company have recently acquired the right to manufacture to five times their present production under the Lilienfeld patent. Courtaulds, Limited, are collaborating in the scientific and technical development of the patent. The suitability of Rayon yarn, produced by this patent, for the manufacture of sewing thread has been established.

THE KIRKLEES ARTIFICIAL SILK MANUFACTURING CO., LTD.

Headquarters	Bury Lanes
Production started	1926
Factory	Tottington Lanes
Process	Viscose
Output (1928)	500,000 pounds per year

APEX (BRITISH) ARTIFICIAL SILK, LIMITED

Headquarters	Stratford
Production started	1928
Factory	Edmonton, London N.
Process	Acetate
Output (Projected)	1,144,000 pounds per year
Capital	£400,000

BRANSON ARTIFICIAL SILK COMPANY, LIMITED

Established	1927
Headquarters	Branston, Burton on Trent
Factory	Branston, Burton on Trent
Process	Viscose
Output Projected	10,000,000 pounds per year
Capital	£1,400,000

This company is one of the most interesting in Great Britain. Financial interest in the company from its inception was surprising and it is reported that the first year's output was contracted for in advance.

BRYSilKA, LIMITED

Established	1920
Headquarters	Bradford
Factory	Bradford
Process	Cupra-ammonium
Capital	£405,000

CELLULOSE ACETATE CO., LTD.

Established	1928
Process	Acetate
Output Projected	5,280,000 pounds per year

NORTH BRITISH COMPANY, LIMITED

Established	1928
Process	Viscose
Output Projected	1,500,000 pounds per year
Capital	£385,000

THE RAYON INDUSTRY

RAYON MANUFACTURING COMPANY, LIMITED

Established	1925
Production started	1927
Headquarters	London
Factory	Ralstead Surrey
Process	Viscose

This company has recently just escaped dissolution by a reconstruction program.

SCOTTISH ARTIFICIAL SILK, LIMITED

Established	1927
Factory	Newton, Cheshire
Process	Viscose
Output Projected	286,000 pounds per year
Capital	£250,000

SUNSHEN COMPANY, LIMITED

Established	1925
Production started	1927
Process	Viscose
Output Projected	1,320,000 pounds per year
Capital	£350,000

YORKSHIRE COMPANY, LIMITED

Established	1928
Process	Viscose
Output Projected	1,000,000 pounds per year
Capital	£325,000

TABLE II.—SUMMARY OF RAYON PLANTS IN ENGLAND

Company	Number of Factories			
	Vis.	A.	C.A.	N.C.
Courtaulds, Limited	3	I		
British Celanese, Ltd.		2		
The British Enka	I			
Western Viscose	I			
British Acetate, Ltd. (Bulmer Rayon) ..	I	I		
Harlens	I			
British Visada	I			
Kemil, Ltd.	I			
Nuera Art-Silk	I			
Kirklees	I			
Apex		I		
Branston	I*			
Brysilka			I	
Rayon Mfg. Co.	I			
Sunsheen	I			
Total	14	5	I	

* Factory under construction.

GERMANY

The condition of the Rayon industry in Germany has been different from all other countries for two reasons:

(1) The World War, retarded greatly, practically stopping, the production of Rayon yarn.

(2) The condition of the Mueller patents covering the Viscose process.

In the first case it was very difficult to obtain raw materials and chemicals and all that could be obtained were needed primarily for war purposes. While this condition existed in all the belligerent countries, it was greatly enhanced in Ger-

many because of her beleaguered position. In the second case the patents of Dr. Max Mueller secured to their holders practically a monopoly of the production of Viscose yarn. The Vereinigte Glanzstoff-Fabriken A. G. controlled these patents in Germany and it became necessary for other manufacturers of Viscose yarns to secure a license from this organization. This naturally retarded the activities of those seeking to enter the field and accounts for the relatively small number of Rayon companies compared to England, Italy and France.

The condition existing in the Viscose field does not exist in the cupra-ammonium, acetate and nitro-cellulose fields, therefore there has been greater activity in newer companies manufacturing by these latter processes. The principal Mueller patents expired in May of 1928, therefore conditions in the Viscose field may undergo a complete change.

The manufacture of Rayon in Germany has steadily increased since the War and in 1927, 35,500,000 pounds were produced. In Table 12 the production, by years is shown. Germany is an exporting country. See tables on imports in Chapter VII on Trade Economics.

TABLE 12.—GERMAN PRODUCTION

Year	Production, Pounds	Year	Production, Pounds
1924	23,700,000	1926	26,000,000
1925	27,100,000	1927	35,500,000
		1928	41,000,000

There are three principal Rayon companies in Germany, the Vereinigte Glanzstoff-Fabriken A.G.; J. P. Bemberg A.G. and I.G. Farbenindustrie A.G. owning separately and together many subsidiary companies. Between them they control most of the Rayon production.

VEREINIGTE GLANZSTOFF-FABRIKEN ACTIEN GESELLSCHAFT

Headquarters	Elberfeld
Factories	(1) Oberbruch bei Heinz- berg (2) Waldneil bei Duelken
Processes	Viscose, Cupra-ammonium and Acetate
Denier	All
Capital	42,600,000 Reichmarks
Subsidiary Companies	(1) Stapelfasenfabrik Jor- dan & Co. (2) Vereinigte - Kunstsei- defabriken A.G. (3) Bayerisole Glanzstoff Fabrick A.G. (4) Glanzfaeden A.G. (5) Deutsche Celta
Associated Companies ...	(1) J. B. Bemberg A.G. (2) Aceta G.m.b.H. (3) Glanzstoff - Courtaulds A.G. (4) Neue Glanzstoffewerke A.G.

Subsidiary Companies

(1) STAPELFASERFABRIK JORDAN & CO.

Headquarters	Elberfeld
Factory	Sydowsane bei Stetten
Process	Viscose
Denier	150, 180, 300
Capital	3,282,000 Reichmarks

The Vereinigte Glanzstoff owns about 99 per cent of this company.

(2) VEREINIGTE KUNSTEIDE-FABRIKEN A.G.

Headquarters	Elberfeld
Factory	Kelsterbach
Process	Viscose
Denier	100, 120
Capital	3,000,000 Reichmarks

The Vereinigte Glanzstoff owns about 92 per cent of this company.

(3) BAYERISCHE GLANZSTOFF-FABRIKEN A.G.

Headquarters	Elberfeld
Factory	Obernburg
Process	Viscose
Denier	120, 150, 180
Capital	2,000,000 Reichmarks

The Vereinigte Glanzstoff owns 100 per cent of this company.

(4) GLANZFALDEN A.G.

Headquarters	Berlin
Factory	Petersdorf im Riesengeb
Process	Viscose
Denier	All

This company owned by Vereinigte Glanzstoff and its subsidiaries. Manufactures also Artificial Straw and Artificial Horsehair.

(5) DEUTSCHE CELTA A.G.

Headquarters	Elberfeld
Process	Viscose (Celta)
Denier	All
Capital	750,000 Reichmarks

Vereinigte Glanzstoff owns 70 per cent of this company.

Associated Companies of Vereinigte-Glanzstoff

(1) J. B. BEMBERG A.-G.

Headquarters	Barmen-Rittershausen
Factories	(1) Barmen
	(2) Oehde
	(3) Augsburg
	(4) Koefeld
Process	Cupra-ammonium
Denier	All
Capital	16,000,000 Reichmarks

This company has a working agreement with Vereinigte Glanzstoff. Proportional participation of Glanzstoff is assured through operations in associated companies.

(2) ACETA G.M.B.H.

Headquarters and Factory	Berlin-Lichtenberg
Process	Acetate
Capital	2,000,000 Reichmarks

Vereinigte Glanzstoff and I. G. Farbenindustrie A.G. each own 50 per cent of this company.

(3) GLANZSTOFF-COURTAULDS A.G.

Headquarters	Elberfeld
Factory	Cologne
Process	Viscose
Deniers	All
Capital	2,000,000 Reichmarks

Vereinigte Glanzstoff and Courtaulds, Ltd. of England each own 50 per cent of this company.

(4) NEUE GLANZSTOFFWERKE A.G.

Headquarters	Elberfeld
Factory	Cawallen (also Breslau)
Capacity	8,800 pounds per day
Process	Viscose
Capital	12,000,000 Reichmarks

This company is the successor to the Gieseles Erben factory. Vereinigte Glanzstoff is interested with the heirs of Georg von Giesch. The factory is being reconstructed and was producing in the summer of 1928.

J. P. BEMBERG

Headquarters	Barmen-Rittershausen
Factories	(1) Barmen
	(2) Oehde
	(3) Augsburg
	(4) Krefeld
Process	Cupra-ammonium
Deniers	All
Capital	16,000,000 Reichmarks
Associated Companies	(1) Vereinigte Glanzstoff-Fabriken A.G.
	(2) Holkenseide G.m.b.H.

(1) VEREINIGTE GLANZSTOFF-FABRIKEN A.G.

(See above)

(2) KOLKENSEIDE G.M.B.H.

Headquarters	Barmen
Factory	Barmen-Rittershausen
Process	Cupra-ammonium
Deniers	80-120
Capital	3,000,000 Reichmarks

J. P. Bemberg and I. G. Farbenindustrie A. G. each own 50 per cent of this company.

I. G. FARBENINDUSTRIE A. G.

Headquarters	Frankfurt on Main
Process	Viscose, Cupra-ammonium and Acetate
Subsidiary Companies	(1) Actien Gesellschaft fuer Ainlein Fabrikation
	(2) Kolm-Rottweil A.G.
Associate Companies	(1) Aceta G.m.b.H.
	(2) Holkenseide G.m.b.H.

Subsidiary Companies

(1) ACTIEN GESELLSCHAFT FÜR ANILIN FABRIKATION

Headquarters	Berlin
Factory	Wolfen bei Bittenfeld
Process	Viscose
Deniers	All

This company owned by I. G. Farbenindustrie A. G.

(2) KOHN ROTTWEIL A.G.

Headquarters	Frankfurt on Main
Factories	(1) Rottweil
	(2) Premnitz
	(3) Robingen
Process	Viscose

Associate Companies

(1) ACETA G.M.B.H.

(See above)

(2) HOLKENSEIDE G.M.B.H.

(See above)

BORVISK KUNSTSEIDEN A. G.

Headquarters and Factory. Herzberg

ProcessViscose

Capital5,000,000 Reichmarks

TABLE 13.—SUMMARY OF RAYON PLANTS IN GERMANY, 1927

Company	Number of Plants			
	Vis.	C.A.	A.	N.C.
Vereinigte Glanzstoff-Fabriken A.G.....	2			
Subsidiary companies:				
(1) Stapelfaserfabrik Jordan & Co.....	I			
(2) Vereinigte Kunstseide Fabriken A.G.....	I			
(3) Bayerische Glanzstoff-Fabriken A.G.....	I			
(4) Glanzfaeden A.G.....	I			
(5) Deutsche Celta A.G.....	I			
Associated companies:				
(1) Aceta G.m.b.H.....			I	
(2) Glanzstoff-Courtaulds.....	I			
(3) Neue Glanzstoffwerke A.G.....	I			
J. P. Bemberg A.G.....		4		
Associated company:				
Kolkenseide G.m.b.H.....		I		
I. G. Farbenindustrie A.G.				
Subsidiary companies:				
(1) A. G. fuer Anilin Fabrikation.....	I			
(2) Kolm Rottweil A.G.....	3			
Borvisk Kunstseiden A.G.....	I			
Fr. Kuettner A.G.....	2*			
Herminghaus & Co.....	2			
Kunstseide Fabrik Schwetzingen G.m.b.H.....				I
Spinnfaser A.G.....	I			
Spinnstofffabrik Zehlendorf G.m.b.H.....	I			
Spinnstoffwerke Glauchau A.G.....	I			
Viskose A.G.....	I			
Total.....	22	5	I	I

* Also cupra-ammonium process.

FR. KUETTNER A. G.

Headquarters	Sehma i/Erzg
Factories	(1) Sehma
	(2) Pirna Ad. Elbe
Output	10,000,000 pounds per year
Processes	Viscose and Cupra-ammonium
Deniers	90-360

HERMINGHOUSE & Co.

Headquarters	Elberfeld
Factories	(1) Vohwinkel
	(2) Wulfrath
Process	Viscose
Deniers	120, 150, 180, 300

KUNSTEIDE FABRIK SCHWETZINGER G.M.B.H.

Headquarters and Factory.	Schwetzingen
Established	1920
Process	Nitro

SPINNFASER A. G.

Headquarters and Factory.	Elsterberg, Saxony
Process	Viscose
Deniers	120, 150, 180, 300
Capital	3,970,000 Reichmarks

SPINNSTOFFFABRIK ZEHLENDORF G.M.B.H.

Headquarters and Factory.	Zehlendorf
Output	10,000 pounds per day
Process	Viscose
Deniers	120-180

This company also manufactures "Spinstro," a special viscose fiber for spinning in accordance with the worsted, woolen and cotton spinning system.

THE RAYON INDUSTRY

SPINNSTOFFWERK GLANELAN A.G.

Headquarters and Factory.	Glanelan, Saxony
Process	Viscose
Deniers	120-300
Capital	2,500,000 Reichmarks

VISKOSE A.G.

Headquarters and Factory.	Arnstadt, Thurmgen
Process	Viscose
Capital	1,000,000 Reichmarks

FRANCE

It is to France and to Count Chardonnet, a Frenchman, that the world is indebted for the manufacture of artificial textiles. Rayon yarn, or as it was termed, artificial silk, was first produced in 1890 at Besançon by the nitro-cellulose process, also known as the Chardonnet process. Not long after, other processes were started such as the cupra-ammonium at Givet and the viscose at Argues and Vals, France.

During the World War, the production of Rayon in France was naturally curtailed, but production for export purposes continued, and in 1915 the value of Rayon yarn and fabrics exported amounted to 12½ million gold francs.

The plants at Givet and Fresury were destroyed and in ruins at the time of the Armistice and the industrial situation with respect to Rayon manufacture was very poor indeed, but so great was the demand for this fiber throughout the world that it was not long before the industry became firmly established. The Givet works of La Soie Artificielle were rebuilt and the Fresnoy plant replaced by the one at Gauchy of the Soie Artificielle de Gauchy. Many other companies were

formed and began operations in the years immediately succeeding the Armistice and production increased rapidly. In order to meet the demand, production had to be supplemented by considerable imports from other countries.

The Rayon industry in France is fortunate in that the necessary chemicals are manufactured in large quantities in the country and there are abundant supplies of suitable water, a matter of the greatest importance in the production of Rayon. On the other hand there are severe handicaps to be contended with for certain local authorities do not favor manufacturing operations where the plant capacity exceeds 1500 Bg. to 2000 Kg. per day, with the result that manufacture is distributed among a great many small factories widely scattered, often with a scarcity of proper labor. Again the Rayon industry is almost entirely dependent on outside sources for its supply of cellulose, the basic raw material. France is an exporting country of Rayon as can be noted from tables in Chapter VII on Trade Economics.

In Table 14 is given the production of Rayon yarn by years.

TABLE 14.—PRODUCTION IN FRANCE

Year	Production, Pounds	Year	Production, Pounds
1924	12,300,000	1926	17,500,000
1925	14,400,000	1927	19,800,000
		1928	30,000,000

The most important organization in the French Rayon industry is the Comptoir des Textile Artificiels. The Rayon producers of France may be divided into two groups—

- (1) Members of the Comptoir
- (2) Non-members of the Comptoir.

THE RAYON INDUSTRY

(1) *Members of the Comptoir*

LA SOIE ARTIFICIELLE

Headquarters	Paris
Factory	Givet (Ardennes)
Process	Viscose
Output	6,000 pounds per day
Capital	1,500,000 francs

SOCIÉTÉ FRANÇAISE DE LA VISCOSE

Headquarters	Paris
Factory	Arques la Bataille
Process	Viscose
Output	8,500 pounds per day
Capital	6,000,000 francs

The capital of this company, two-thirds of which is held by La Soie Artificielle, has been redeemed. Profits of the company in 1926 amounted to over 11,000,000 francs. It is reported to be connected, and possibly allied with the DuPont Rayon Co. of U. S. A.

SOCIÉTÉ SUISSE DE LA VISCOSE

Headquarters	Paris
Capital	7,800,000 francs

The capital of this company has been redeemed and in 1926 its profits were nearly 13,000,000 francs. It is no longer engaged in the production of Rayon in France but confines its activities to the control of its Swiss subsidiary which owns several factories.

SOCIÉTÉ ARDECHOISE POUR LA FABRICATION DE LA SOIE DE VISCOSÉ

Headquarters	Paris
Factory	Vals-les-Bains
Process	Viscose
Output	4,000 pounds per day
Capital	2,100,000 francs,

The capital of this company has been redeemed and its profit for 1926 was 3,500,000 francs.

SOCIÉTÉ ALBIGEOISE DE LA VISCOSÉ

Headquarters	Paris
Factory	Albi
Process	Viscose
Output	4,000 pounds per day
Capital	8,500,000 francs

The profits of this company for 1926 were 4,500,000 francs.

SOIE ARTIFICIELLE D'ALSACE

Headquarters	Paris
Factory	Colmar
Process	Viscose
Output	11,000 pounds per day
Capital	50,000,000 francs

SOIE ARTIFICIELLE DE BESANÇON

Headquarters	Paris
Factory	Besançon
Process	Viscose
Output	3,300 pounds per day
Capital	2,000,000 francs

This company uses the old Chardonnet factory at Besançon. Its profit in 1925 was over 3,000,000 francs. The

THE RAYON INDUSTRY

Comptoir saved the old Chardonnet company by making it change its process to Viscose.

SOIE ARTIFICIELLE D'IZIEUX

Headquarters	Paris
Factory	Izieux
Output	6,000 pounds per day
Process	Viscose
Capital	8,000,000 francs

The profits of this company in 1926 were over 8,000,000 francs.

SOCIÉTÉ NOUVELLE DE SOIE ARTIFICIELLE

Headquarters	Paris
Factory	Saint-Aubin
Process	Viscose
Output	1,500 pounds per day
Capital	6,000,000 francs

This company was formed under the auspices of the Comptoir.

SOCIÉTÉ POUR LA FABRICATION DE LA SOIE RHODIASETA

Headquarters	Paris
Factories	(1) Roussillon
	(2) Saint-Fous
	(3) Lyon Vaise
Process	Acetate
Denier	60-150
Output (combined)	8,000 pounds per day
Capital	3,000,000 francs

This company is a subsidiary of the Société Chimique des Usines du Rhone.

SOCIÉTÉ NATIONALE DE LA VISCOSE

Established	1925
Headquarters	Paris
Factory	Grenoble
Process	Viscose
Output	2,200 pounds per day
Capital	150,000,000 francs

While the output of this company's factory is only 2,200 pounds per day its capacity is 17,000 pounds per day, which ultimately will be increased to 25,000 pounds per day.

SOCIÉTÉ DE LA SOIE DE ST.-CHAMOND

Headquarters	Paris
Factory	Saint-Chamond
Process	Viscose
Output	2,400 pounds per day
Capital	2,500,000 francs

SOCIÉTÉ FRANÇAISE DE CRINS ARTIFICIELLE

Headquarters	Paris
Factory	Saint-Juste des Marcis
Process	Viscose
Output	Rayon yarn—2,200 pounds per day Artificial Straw and Arti- ficial Horse hair—2,000 pounds per day
Capital	800,000 francs

COMPAGNIE NOUVELLE DES APPLICATIONS DE LA CELLULOSE

Headquarters	Paris
Factory	Gauchy
Process	Viscose
Output	"Celta"—Tubular Rayon, 4,400 pounds per day
Capital	6,000,000 francs

THE RAYON INDUSTRY

SOIE ARTIFICIELLE DU SUD-EST

Headquarters	Paris
Factories	(1) Vaux-en-Velin
	(2) La Voulte-sur Rhone
Process	Viscose
Output	15,000 pounds per day
Capital	6,000,000 francs

The capacity of this company's factories are to be increased in the immediate future.

SOCIÉTÉ "LE CUPROTEXTILE"

Headquarters	Paris
Factory	Roanne
Process	Cupra-ammonium
Output	1,750 pounds per day
Capital	10,000,000 francs

A German group, Bemberg-Barmen, is interested in this company with the Comptoir.

(2) *Non-Members of the Comptoir*

SOIE DE VALENCIENNES

Headquarters and Factory.	Valenciennes
Process	Viscose
Output	2,000 pounds per day
Capital	35,000,000 francs

This company is controlled by the Dutch "Breda" group. Its profits in 1926 were 2,500,000 francs.

SOCIÉTÉ LYONNAISE DE SOIE ARTIFICIELLE

Headquarters	Lyons
Factory	Decines
Process	Viscose
Denier	150, 200, 300
Output	3,000 pounds per day
Capital	40,000,000 francs

This company is controlled by the Dutch "Enka" group. Its profits in 1926 were nearly 4,000,000 francs.

SOIRES DE STRASBOURG

Headquarters and Factory.	Strasbourg (Alsace)
Process	Viscose
Production	2,200 pounds per day
Capital	31,000,000 francs

This company is controlled mainly by Alsatian capital with a small holding by Courtaulds, Ltd. of England.

SOIE ARTIFICIELLE DE CALAIS

Headquarters and Works.	Coquelle (Calais)
Process	Viscose
Capital	10,000,000 francs

This company owned by Courtaulds, Ltd. of England, started production late in 1927.

SOCIÉTÉ FRANÇAISE DE TUBIZE

Headquarters	Venissieux
Factories	(1) Grand-Quevelly (2) Venissieux
Process	Acetate
Output	2,200 pounds per day
Capital	65,000,000 francs

This company is controlled by Tubize with minority holdings in the hands of Lyons capitalists. Its profits in 1926 were 2,250,000 francs.

LA SOIE ARTIFICIELLE FRANÇAISE

Plant	Reunes
Process	Nitro-cellulose
Capital	6,000,000 francs

This company went into liquidation. All of its assets have been acquired by an English group.

THE RAYON INDUSTRY

INTERNATIONAL ARTIFICIAL SILK LIMITED

Headquarters	Paris
Factories	(1) Clairoux
	(2) Aubenton
Process	Viscose
Output	11,000 pounds per day

This company represents the re-organization of the Société de la Soie de Compiègne and its sister company the Soie d'Aubenton.

LA SOIE D'ARGENTEUIL

Headquarters and Factory.	Argenteuil
Process	Viscose
Output	1,500 pounds per day
Capital	8,500,000 francs

This company made a profit of 600,000 francs in 1926. The factory was originally used as an alcohol distillery.

SOCIÉTÉ FRANÇAISE DE TEXTILES NEO-SOIE ET NEO-LAINS

Factory	Iriguy
Process	Viscose
Capital	12,000,000 francs

This company was formed in 1927 for the manufacture of Rayon for table fabrics. It started production in 1928.

SOIE DE VALENCE

Headquarters	Paris
Factories	(1) Avignon
	(2) Valence
Process	Viscose
Denier	150, 200, 300
Output	8,800 pounds per day
Capital	15,000,000 francs

SOIE DE FEYZIN

Headquarters and Factory.	Feysin
Process	Viscose
Output	2,200 pounds per day
Capital	4,100,000 francs

SOIE ARTIFICIELLE D'AMIENS

Process	Viscose
Capital	16,333,300 francs

This company was formed in March, 1927.

S.A. POUR LE FABRICATION DE LA SOIE ARTIFICIELLE
"BORVISK"

Headquarters	Paris
Factory	Nevers
Process	Viscose
Output	2,400 pounds per day
Capital	20,000,000 francs

Since November, 1927, this company has been controlled by a French group consisting of Kuhlmann et Cie, Agaele Fils and the Société Dolfuss Mieg et Cie.

SOCIÉTÉ DES TEXTILES CHIMIQUES DU NORD ET DE L'EST

Capital	50,000,000 francs
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This company was founded in November, 1927, by the French group which controls the S. A. pour la Fabrication de la Soie Artificielle "Borvisk."

THE RAYON INDUSTRY

LA SOIE VAUBAN

Headquarters	Paris
Factory	Conde-sur-Escant (Nord)
Process	Viscose
Output	660 pounds per day
Capital	12,000,000 francs

FILATURE DE SOIE ARTIFICIELLE DE LA BUSSIÈRE

Factory	Flarigny-le-grand
Process	Viscose
Capital	10,000,000 francs

LA SOYEUSE FRANÇAISE

Factory	Rantigny
Process	Viscose
Capital	12,500,000 francs

S.A. DES TEXTILES SYNTHETIQUES

Factory	Premilhat
Process	Viscose
Capital	5,000,000 francs

S.A. DE LA TEXTILE DU JANON

Factory	'Terre-Noire
Capital	1,050,000 francs

LA SOIE ARTIFICIELLE DE SAINT ETIENNE

Factory	Neuvelle-sur-Savne
Process	Viscose
Capital	3,600,000 francs

THE PRODUCTION OF RAYON

97

TABLE 15.—SUMMARY OF RAYON PRODUCING COMPANIES IN FRANCE, 1927

Company	Number of Plants			
	Vis.	A.	C. A.	N. C.
<i>Comptoir Members:</i>				
La Soie Artificielle.....	I			
Société Française de la Viscose.....	I			
Société Ardichoise de la Viscose.....	I			
Société Albigeoise de la Viscose.....	I			
Soie Artificielle d'Alsace.....	I			
Soie Artificielle de Besançon.....	I			
Soie Artificielle d'Izieux.....	I			
Société Nouvelle de Soie Artificielle.....	I			
Société "Rhodiaseta".....		3		
Société Nationale de la Viscose.....	I			
Soie de Saint-Chamond.....	I			
Société Française des Coins.....	I			
Applications de la Cellulose.....	I			
Soie Artificielle du Sud-Est.....	2			
Société "Le Cuprotextile".....			I	
<i>Non-Comptoir Members:</i>				
Soie de Valenciennes.....	I			
Société Lyonnaise.....	I			
Soiries de Strasbourg.....	I			
Soie Artificielle de Calais.....	I			
Société Française de Tubize.....		2		
La Soie Artificielle Française.....				I
International Artificial Silk, Ltd.....	2			
La Soie d'Argenteuil.....	I			
Société des Textiles Neo-Soi et Neo-Lains.....	I			
Soie de Valence.....	2			
Soie de Feyzin.....	I			
Société "Borvisk".....	I			
La Soie Vauban.....	I			
Filatures de la Bussière.....	I			
La Soyeuse Française.....	I			
S. A. des Textiles Synthétiques.....	I			
La Soie de Saint Etienne.....	I			
Total.....	31	5	I	I

HOLLAND

The production of Rayon in Holland began in 1912 but did not amount to much until after the World War. As in other countries the production of Rayon yarn in Holland has been steady and rapid and while only two companies are manufacturing, they have kept increasing their capacities in an attempt to keep up with the ever-increasing demand.

Production in 1926 was three times that of 1925 and 1927 was nearly four times that of 1925. The exports for 1925 possibly include a carry-over from the previous year.

In Table 16 is shown the production for Holland by years. Holland is an exporting country as will be seen from tables in Chapter VII on Trade Economics.

TABLE 16.—PRODUCTION IN HOLLAND

Year	Production, Pounds	Year	Production, Pounds
1924	3,400,000	1926	13,500,000
1925	4,400,000	1927	16,500,000
		1928	16,500,000

N. V. HOLLANDSCHE KUNSTZIJDE INDUSTRIE BREDA

Headquarters Rotterdam

Factory Breda-North Brabant

Process Viscose

Denier 90-900

Output 10,000 pounds per day

Capital 10,000,000 florins

This company is associated with S. A. la Soie de Valenciennes France, Consortium Industriel de la Soie at Breda, Brussels and Paris and S. A. La Seda of Barcelona, Spain. Breda's net profit for 1926 was 1,298,159 florins. Plans for factory extensions will increase capacity to 1500 pounds per day.

N. V. NEDERLANDSCHE KUNSTZYDEFABRIEK (ENKA)

Headquarters	Arnheim
Factories	(1) Arnheim
	(2) Ede
Process	Viscose
Denier	80 to 1,000
Output	50,000 pounds per day
Capital	10,000,000 florins

This company, known as the "Enka" is associated with the British Enka and American Enka, also with the N. V. Mackubee, a company for the exploitation of Rayon factories in foreign countries. A large spinning factory is also in operation in Rotterdam.

BELGIUM

The production of Rayon in Belgium began very early in the existence of this synthetic fiber. In 1913 it produced 3,000,000 pounds, most of which was exported either as fiber or fabric. During the World War the production of Rayon practically ceased for most of the factories were in enemy hands and the plants were dismantled so that Belgium had practically to begin all over again after the War.

Production in Belgium as in other countries has been steady and continuous and expansion programs are being considered on all sides to meet the ever-increasing demand for Rayon, both domestic and for export. Belgium is an export country which can be seen from tables in Chapter on Trade Economics.

TABLE 17.—PRODUCTION IN BELGIUM

Year	Production, Pounds	Year	Production, Pounds
1924	8,900,000	1926	13,100,000
1925	11,100,000	1927	13,500,000
		1928	15,000,000

THE RAYON INDUSTRY

FABRIQUE DE SOIE ARTIFICIELLE DE TUBIZE

Headquarters	Tubize
Factories	Three
Processes	Viscose—40 per cent Acetate—20 per cent Nitro-cellulose—40 per cent
Output (combined)	20,000 pounds per day
Capital	25,000,000 francs

The Tubize is one of the oldest Rayon companies and is associated with companies in U. S. A., France, Poland, etc.

SOCIÉTÉ GENERALE DE SOIE ARTIFICIELLE

Headquarters	Brussels
Factory	Alost
Process	Viscose
Output	4,400,000 lbs.
Capital	5,250,000 francs

LA SETA (FABRIQUE DE SOIE ARTIFICIELLE) S.A.

Headquarters	Brussels
Factory	Ecaussines
Process	Viscose
Capital	8,000,000 francs

This company is associated with the Société Generale de Soie Artificielle.

SOCIÉTÉ ANVERSOISE DE SOIE ARTIFICIELLE

Headquarters	Antwerp
Factory	Schooten
Process	Viscose
Capital	10,000,000 francs

This company is associated with the Société Generale de Soie Artificielle.

FABRIQUE DE SOIE ARTIFICIELLE D'OBOURG

Headquarters	Obourg-ley-Mons
Factory	Blanc Misseron
Process	Viscose
Output	10,000 pounds per day
Denier	Nitro-cellulose—40-180
	Viscose—90-200
Capital	10,000,000 francs

SOCIÉTÉ DE TEXTILES BELGES S.A.

Headquarters	Obourg
Factory	Blanc Misseron
Process	Viscose
Output	10,000 pounds per day
Capital	1,500,000 francs

This company is associated with the Fabrique de Soie Artificielle d'Obourg. Its profit for years 1924-1925 was over 3,900,000 francs.

S.A. DES SOIERIES DE MARANSART

Headquarters and Factory	Couture St. Germain
Processes	Nitro-cellulose
	Viscose
Denier	Nitro-cellulose—70-300
	Viscose—All
Capital	7,500,000 francs

SOIE DE VAUBAN

Factory	Conde
Process	Viscose

SOCIÉTÉ INDUSTRIELLE DE LA CELLULOSE

Factory	Ghent
Process	Viscose

TABLE 18.—SUMMARY OF PRODUCING COMPANIES IN BELGIUM, 1927

Company	Number of Plants			
	Vis.	A.	N. C.	C. A.
Fabrique de Soie Artificielle de Tubize.....	I	I	I	
Société Generale de Soie Artificielle.....	I			
La Seta S. A.....	I			
Société Anversoise de Soie Artificielle.....	I			
Fabrique de Soie Artificielle d'Obourg.....	I*			
Société de Textiles Belges S. A.....	I			
S. A. des Soiries de Maransart.....	I*			
Soie de Vauban.....	I			
Société Industrielle de la Cellulose.....	I			
Total.....	9	I	I	

* Also produces by nitrocellulose process.

SWITZERLAND

The production of Rayon in Switzerland began early in the history of this fiber but the original producers did not survive. The first of the present companies to manufacture was the Société de la Viscose Suisse which started operations about 1906. Today there are five factories in operation with a new company ready to build the sixth factory in the near future.

Owing to the fact that practically all raw materials and machinery for producing Rayon have to be imported into the country and on account of high labor cost, manufacturing costs are high in Switzerland, and the producing companies specialize in the production of high grade yarns which find a ready market.

About one-third of all the Rayon Switzerland produces is consumed in the country itself, the consumption per head

THE RAYON INDUSTRY

KUNSTSEIDE VERTRIEBS GESELLSCHAFT

Headquarters and Factory. Steckhoom
 Process Viscose

This company was originally the "Borvisk" Kunstseiden Werk A. G. but the Swiss interests now control the Company.

NOVASETA A. G. OF ARBON

This company has recently been launched by interests headed by Heberlein & Co. It has secured the factory of the late Seeriet A. G., a dyeing concern at Arvon on Lake Constance. It is reported that this company intends to produce Rayon by both the Acetate and Cupra-ammonium processes.

TABLE 20.—SUMMARY OF RAYON COMPANIES OPERATING
 IN SWITZERLAND, 1927

Company	Number of Plants			
	Vis.	A.	N. C.	N. A.
Société de la Viscose Suisse S.A.....	2			
Feldmuehle Rorsebach A.G.....	1			
S. A. Viscose Rheinfelden Suisse.....	1			
Kunstseide Vertriebs Gesellschaft.....	1			
Total.....	5			

AUSTRIA

The only Rayon factory in Austria is the Ersto Oesterreichische Glantzstoff-Fabrick at St. Belten near Vienna, producing by the Viscose process. This plant has operated on a capacity basis for several years; and the company has developed substantial export business in addition to supplying the

home market. This company was founded in 1904 with a capital of 90 million crowns.

TABLE 21.—PRODUCTION IN AUSTRIA

Year	Production, Pounds	Year	Production, Pounds
1925	3,500,000	1927	3,500,000
1926	3,500,000	1928	4,500,000

Austria exports practically all it produces as can be seen from tables in Chapter on Trade Economics.

CZECHO-SLOVAKIA

There are five factories producing Rayon in Czecho-Slovakia. This country is a large consumer of Rayon yarns and its imports are greater than the exports. The large and powerful national cotton and silk industries consume an ever-increasing volume for new channels for Rayon are continuously being developed by them.

Through a recent tariff change the Rayon manufacturers have obtained a certain measure of protection at home. The raw chemical materials, however, have all to be imported, and are subject to a tariff which increases their cost about 25 per cent, thus placing a permanent burden on production costs.

All the factories are working to capacity and plans for

TABLE 22.—PRODUCTION IN CZECHO-SLOVAKIA

Year	Production, Pounds	Year	Production, Pounds
1924	1,300,000	1926	2,800,000
1925	2,000,000	1927	3,500,000
		1928	3,500,000

BOEMISCHE GLANZSTOFF-FABRIK SYSTEM, ELBERFELD

This company is associated with the Vereinigte Glanzstoff-Fabriken A. G. of Elberfeld and the Este Oesterreichische Glantzstoff-Fabrik A. G. of St. Polten.

Headquarters and Factory.	Theresienthal b/Arnan
Process	Viscose
Denier	120 to 1,000
Output	1,600,000 pounds per year
Capital	12,000,000 Crowns (Czech)

Headquarters	Vienna (Austria)
Factory	(1) Mähr Chrostau
	(2) Schoenbrunn
Process	Viscose
Denier	90 to 180
Output	396,000 pounds

All of the Rayon produced by this company is used in its own weaving mills. It is proposed to increase capacity nearly 100 per cent.

ARTIFICIAL SILK SPINNING WORKS, LTD.

Headquarters	Bratislava
Factory	Senica
Process	Viscose
Denier	120 to 600
Output	800,000 pounds per year
Capital	2,000,000 Crowns (Czech)

This company is now controlled by the Tahna Wood Pulp Co., Ltd., Bratislava. The factory was closed down during 1927 for reconstruction, but resumed operations in 1928.

V. VINCIGUERRA

Headquarters	Vienna (Austria)
Factory	Maehr Schoenberg
Process	Viscose
Denier	40 to 2,000
Output	900,000 pounds per day

Also operates 3000 Doublny spindles and 2000 Winding spindles. Associated with Edलगarnspinnerei Amfaldern & Co., Maehr Schoenberg.

TABLE 23.—SUMMARY OF RAYON PRODUCING COMPANIES IN CZECHO-SLOVAKIA

Company	Producing Factories			
	Vis.	A.	N. C.	C. A.
Boemische Glanzstoff-Fabrik System Elberfeld.	1			
Erste Boehmische Kunstseidefabrik A.G.....	1			
Gebrueder Bader Maehr-Chrostau (Post Brunn- litz).....	2			
Artificial Silk Spinning Works Ltd.....	1			
V. Vinciguerra.....	1			
Total.....	6			

SOIE ARTIFICIELLE DE MYSKOWSKA SOCIÉTÉ ANONYME

Headquarters and Factory. Myszkow
 Process Viscose
 Denier 80 to 300
 Output 440,000 pounds per year
 Capital 6,000,000 Zlotys

Associated with Soie Van Ban Conde S/L Escart.

S. A. BELGE DES SOIES ARTIFICIELLES DE SOKHATCHEFF

Headquarters Brussels (Belgium)
 Factory Sokolatcheff
 Process Viscose
 Capital 1,000,000 francs (Belgian)

TABLE 25.—SUMMARY OF RAYON PRODUCING COMPANIES
 IN POLAND, 1927

Company	Number of Plants			
	Vis.	N. C.	A.	C. A.
Tomaszowska Fabryka Sztucznego Yedwabin Sp. Ake.....	1*			
Soie Artificielle de Myszkowska S.A.	1			
S.A. Belge des Soies Artificielles de Sokhatcheff.	1			

* Also produces by Nitro-cellulose process.

SPAIN

There are three Rayon producing companies in Spain all of which have been producing but a few years and none of which are of any great size. In 1927 the imports were 14 times as much as the total production and all companies are making plans to increase production to change this condition.

THE RAYON INDUSTRY

TABLE 26.—PRODUCTION IN SPAIN.

Year	Production, Pounds	Year	Production, Pounds
1924	200,000	1926	300,000
1925	200,000	1927	1,000,000
		1928	2,500,000

FABRIC DE SEDA ARTIFICIAL DE VALDENOCEDA

Headquarters	Santander
Works	Valdenoceda
Process	Viscose
Denier	150 to 3,600
Output	1,760 pounds per day
Capital	3,600,000 pesetas

This company is being reconstructed to increase production 100 per cent.

S. A. SEDA DE BARCELONA

Headquarters	Barcelona
Factory	Prat de Tlobregat
Process	Viscose
Output	1,100 pounds per day
Capital	10,000,000 pesetas

This company is owned by the Consartium Industrielle de la Soie which was in turn organized by the N. Hollandsche Kunstzijde Industrie (Breda) of Holland.

S. A. DE FIBRAS ARTIFICIALES

Headquarters	Barcelona
Factory	Blanes
Process	Viscose
Output	8,800 pounds per day
Capital	12,000,000 pesetas

This company was established in 1923.

SOC. ESPAÑOLA DE SEDA VIZCOSA

Offices in Barcelona expects to produce Rayon by the Viscose method.

TABLE 27.—SUMMARY OF RAYON PRODUCING COMPANIES IN SPAIN

Company	Number of Plants			
	Vis.	A.	N. C.	C. A.
Fabric de Seda Artificial de Valdenoceda	1			
S.A. Seda de Barcelona	1			
S.A. de Fibras Artificiales	1			
Total	3			

GREECE

There is only one Rayon producing factory in Greece located at Patissia.

SOCIÉTÉ ANONYME DE SOIE ARTIFICIELLE "ETMA"

Headquarters Athens
 Established 1925
 Factory Patissia
 Process Viscose
 Output 2,200 pounds per day
 Capital 10,000,000 drachme

In 1927 this company established a subsidiary company in Greece, the Société d'Acetose, for the production of Acetate yarn.

HUNGARY

There is only one Rayon producing factory in Hungary, located at Magyarovar. The plant of the Fabrique de Soie

THE RAYON INDUSTRY

Artificielle which was located at Sarray has been demolished. The I. G. Farbenindustrie of Germany has negotiated in Ofenpest for the construction of a factory. When this factory is built it is intended to supply the Balkan market as well as the domestic.

FABRIQUE DE SOIE ARTIFICIELLE

Headquarters	Sarrar
Factory	Recently demolished
Process	Viscose
Capital	200,000,000 hr.

This company is associated with Tubize.

MAGYAROVARI MUSELYEMGYAR

Headquarters and Factory.	Magyarovar
Process	Nitro-cellulose
Denier	30 to 70

This company belongs to a group consisting of Ung. Allg. Creditbank and Ung. Escompte und Wechshlerbank.

I. G. FARBENINDUSTRIE (GERMANY)

This company is reported to be negotiating for the construction of a Rayon factory at Ofenpest.

SWEDEN

There is only one Rayon producing factory in Sweden located at Boras.

AKTIEBOLAGET-SVENSKT KONSTSILKE

Headquarters and Factory.	Boras
Process	Viscose
Output	385,000 pounds per year

RUSSIA

The government of the U. S. S. R. recently invited Dr. Emile Bronnett of the Soireries de Strasbourg to visit Russia and give his technical assistance to the "Textile Trust of Leningrad" which is a government concern. This trust has just started a Rayon factory to produce 3,300,000 pounds per annum by the Viscose process. Other factories will subsequently be built. For this purpose the government has voted a credit of 85,000,000 roubles. Of producing Rayon factories in Russia, today, there are two.

MOSKAUER STAALICHER VIGOGKE TRUST

Headquarters	Moscow
Factory	Mytischtschi
Process	Viscose
Output	370,000 pounds per year

LA SOIE DE MOSKOW

Headquarters and Factory	Moscow
Process	Viscose

This company is associated with Reisner & Co. of Prague.

IRELAND

There is one Rayon producing company in Ireland located at Gracehill, Ballymena, County Antrim, North Ireland.

SUNSHEIN LIMITED

Established	1925
Headquarters	Liverpool, England
Factory	Gracehill
Process	Viscose
Capital	£350,000

THE RAYON INDUSTRY

NORWAY

Norway's first Rayon factory is being built at Rygge in the vicinity of Moss. The Viscose process will be used and production is to start with about 3,850,000 pounds per year. The cost of the factory will be in the neighborhood of one million crowns.

ASIA

JAPAN

Japan is the only Asiatic country producing Rayon and in spite of the fact that its principal industry is that of silk production it now operates 16 Rayon factories and imports large quantities of Rayon without any exports.

Several of the Japanese Rayon companies are associated with European companies and are getting technical help and advice through such associations.

It is reported that several of the Japanese companies have formed a cartel.

TABLE 28.—PRODUCTION IN JAPAN

Year	Production, Pounds	Year	Production, Pounds
1924	1,200,000	1926	5,500,000
1925	1,400,000	1927	8,000,000
		1928	12,000,000

TEIKOKU JINZO KENSHI KAISHA, LTD.

Headquarters Osaka City
 Factories (1) Yonezawa
 (2) Hiroshima
 (3) Iwakuni
 Process Viscose
 Denier 80 to 600
 Output 22,000 pounds per day
 Capital 21,000,000 yen

This company is associated with the "Snia" Viscosa of Italy.

ASAHI KENSHOKU KABUSHIKI KAISHA

Headquarters	Nichome Yedobori Minamidori
Factories	(1) Zeze-Cho (2) Nobeska
Process	Viscose
Output	12,000 pounds per day

This company is the oldest Rayon producer in Japan. It is associated with the Vereinigte Glanzstoff Fabriken A. G. of Elberfeld, Germany.

TOKYO JINZO KENSHI KAISHA

Headquarters	Tokio
Factory	Yoshiwara
Process	Viscose
Denier	150 to 200
Output	5,000 pounds per day
Capital	500,000 yen

KAWAGOE JINZO KAISHA

Factory	Kawagoe
Process	Viscose
Output	2,000 pounds per day
Capital	100,000 yen

MIE JINZO KENSHI KAISHA

Factory	Matzuzaka
Process	Viscose
Output	2,000 pounds per day
Capital	80,000 yen

THE RAYON INDUSTRY

TOYO RAYON KAISHA

Headquarters	Tokio
Factory	Ishiyama
Process	Viscose
Denier	60 to 300
Output	6,600 pounds per day

Plans will eventually call for 24 tons of Rayon per day.

NIHON RAYON KAISHA

Headquarters	Osaka
Factory	Uji
Process	Viscose
Denier	80 to 300
Output	4,400 pounds per day
Capital	7,500,000 yen

This company is associated with the Japan Cotton Spinning Co., Ltd.

KURASHIKI KENSHOKU KAISHA

Factory	Nokasamura
Process	Viscose
Output	3,300 pounds per day

TOKYO BOSEKI KAISHA

Factory	Katada
Process	Viscose
Output	2,000 pounds per day

NIHON KEORI KAISHA

Factory	Nagoya
Process	Viscose
Output	1,000 pounds per day

MARUWA KENSHOKU KAISHA

Factory Marnoka
 Process Viscose
 Output 1,000 pounds per day

GOSHA KAISHA

Factory Tikeotoyo
 Process Viscose
 Output 1,000 pounds per day

RAYON KAISHA LTD.

Headquarters Tokio
 Factory Otsu
 Process Viscose
 Capital 10,000,000 yen

TABLE 29.—SUMMARY OF RAYON PRODUCING FACTORIES IN JAPAN

Company	Producing Factories			
	Vis.	A.	N. C.	C. A.
Teikoku Jinzo Kaishi K.K.....	3			
Asahi Kenshoku K.K.....	1			
Tokyo Jinzo K.K.....	2			
Kawagoye Jinzo K.....	1			
Mie Jinzo Kenshi K.....	1			
Tokyo Rayon K.....	1			
Nihon Rayon K.....	1			
Kurashiki Jenschoku K.....	1			
Toyo Boseki K.....	1			
Nihon Keori K.....	1			
Maruwa Kenshoku K.....	1			
Gosha K.....	1			
Rayon Kaisha, Ltd.....	1			
Total.....	16			

THE RAYON INDUSTRY

PRODUCTION POSSIBILITIES

It is not many years ago that Rayon was looked upon generally as a cheap and inferior substitute for silk instead of a distinct and separate textile, with its own characteristics as have the natural textiles. Perhaps the opinion was justified to some extent when Rayon was first used, because it had many limitations and the public was not educated up to its characteristics. Today, however, Rayon is recognized as a textile meeting a human need, not only in conjunction with other textiles such as cotton, wool and silk, in which form it overcomes many of the inherent weaknesses of its sister textiles, but alone as a beautiful, soft, warm and silklike textile fabric which appeals to all—men and women.

Today fabrics of pure Rayon woven into articles of wearing apparel for both sexes can be obtained at an equal price with similar garments made entirely of cotton yet with all the appearance of silk and free from many of the objectionable features of both. Under such conditions it is safe to say that the vast majority will turn from cotton garments especially, to Rayon and to a lesser degree from silk also. With this possibility fast becoming a fact—consider to what vast proportions the production of Rayon will extend. In 1928 the world production of Rayon was less than 2 per cent of the production of cotton and estimates made of what the production is likely to be by those considered authorities on the subject, sound miraculous. The Fairchild Analytical Bureau

TABLE 30.—A PROPHECY—WORLD'S PRODUCTION, TONS

Year	Cotton	Wool	Silk	Rayon
1930	5,000,000	2,000,000	20,000	250,000
1935	4,000,000	2,000,000	10,000	2,500,000
1940	3,000,000	2,000,000	5,000	5,000,000

estimates the annual production of Rayon throughout the world will be 500,000,000 pounds in 5 years while the *Financial News* (London, England) predicts that:

Ten billion pounds of Rayon will be produced throughout the world in 1940!

Yet this is a prediction given by investigators, no doubt after weighing conditions carefully. Such figures seem almost unbelievable, yet why should there not be the same demand for Rayon goods as for cotton? But whether this can be accomplished in 12 short years is a matter that the next two or three years will determine. The author predicts that the production of Rayon throughout the world will have reached the stupendous quantity of one billion pounds, or four times what it is today, in the next ten years, and at that rate the production will be easily absorbed by the textile trade.

COMPARATIVE QUALITY

The quality of Rayon produced throughout the world has improved greatly in the past few years. Rayon yarns manufactured in the United States have always been considered of superior quality, in fact, better than almost all other yarns produced throughout the world. Much of the imported Rayon into the United States in past years has been of a very poor quality, the denier varying so in the same packages that weaving operations have been greatly handicapped. This condition no doubt was responsible for the bad reputation in which Rayon goods were held, but conditions universally have so improved that the tendency is to produce superior goods of Rayon yarns because of the higher prices which they demand. This is especially so in the countries where the cost of importing raw materials, and the cost of labor is so high, that to produce the ordinary grades of yarns and sell them in competition with others, would be impossible or not sufficiently remunerative to justify the effort.

CHAPTER IV

PRODUCTS OTHER THAN RAYON OBTAINED FROM CELLULOSE SOLUTIONS

IN addition to the ordinary commercial Rayon yarns produced from cellulose solutions prepared specially for that purpose, there are at present many other commercial products obtained, and extensive research work is continually revealing, first in laboratory form, then in commercial form, other products of original and synthetic natures which are meeting many human needs both efficiently and economically. These products may be broadly classified under two main headings.

A. Those obtained from the viscous cellulose solutions.

B. Those obtained after the solutions have been passed through a neutralizing bath into filament form.

Under the former division we may consider the following:

- (1) Films.
- (2) Celaphane.
- (3) Sausage Casings.
- (4) Unshatterable Glass.
- (5) Waterproofing.
- (6) Wallpaper Surfacing.
- (7) Paints and Lacquers.
- (8) Covering for Paper and Metallic Gauze.
- (9) Sizing for Fabrics and Threads.
- (10) Viscose-Rubber.
- (11) Viscose Leathers.
- (12) Insulation Plates.

(1) FILMS

Cellulose acetate is particularly adapted for photographic films and is largely used as such in motion picture and other

industries because films so obtained are not inflammable. Prior to the use of cellulose acetate, films were made from cellulose prepared by the Chardonnet, nitro-cellulose, process, but as films so made are inflammable the tendency is to change to the newer and more desirable product.

(2) CELAPHANE

Celaphane is a thin film produced by extruding the cellulose through a narrow slit into an acidulated glycerine bath and winding up the resulting smooth, stiff, transparent sheet, resembling isinglass or photo films. It is dyed in many colors, including metallic and iridescent effects, and it can be etched, lacquered, embossed, crimped and pleated. Celaphane is also known to trade as "fenestre" paper, "Glassolyn," "flexaloid," etc. Its principal uses are for candy box wrappers, bags, window covers, bottle caps, wrappers for cosmetic and pharmaceutical preparations, etc. When cut into strips, it is also woven into cloth and braid used in the millinery trade.

(3) SAUSAGE CASINGS

Experiments are being carried on with casings of cellulose for sausages and other edible products. Because of the difficulty in cleansing and purifying animal casings, it would seem logical that a cellulose casing, which can be made extremely thin and, being a non-injurious vegetable product, should answer this purpose.

(4) UNSHATTERABLE GLASS

Unshatterable or unbreakable glass, as it is called, is now being produced by having a filler which is a sheet either of nitro-cellulose or cellulose-acetate. This filler is placed be-

tween sheets of glass and the glass adheres tenaciously to the cellulose sheet, thus preventing glass splinters from scattering.

(5) WATERPROOFING

In order to use cellulose solutions for waterproofing purposes, experiments are constantly being carried on. Paper containers are being treated with a solution of cellulose making the container very desirable for cement and other hydroscopic materials.

(6) WALLPAPER SURFACING

There has recently been developed a method of economically applying a cellulose solution to the surface of wallpaper which, when used on the cheapest grades, gives it the appearance of the most expensive. It not only waterproofs the surface of the paper, but permits it to be washed with soap and water as painted walls are today. Delicate colors and tints which fade readily are protected and preserved by its use and any wall paper so treated is considerably improved in appearance. However, the greatest improvement is shown when used on the cheapest grades, therefore the method is economical from all angles.

(7) PAINTS AND LACQUERS

As a result of experiments, it is hoped that cellulose solutions will be used in increasing quantities in paints and lacquers. On account of its waterproofing qualities and its excellent adherence, it would be most desirable. Also paints containing such solutions when dry should present a hard, smooth surface unaffected by alkali soaps.

(8) COVERING FOR PAPER AND METALLIC GAUZE

Cellulose is used as a film for paper in many forms and applications and also for metallic gauze and other such goods. As explained above such films present smooth, hard, water-proof surfaces which are sanitary and easily cleaned.

(9) SIZING FOR FABRICS AND THREADS

Cellulose is being applied for sizing purposes, especially for all kinds of fabrics and threads, because of its smooth, hard, waterproof qualities and its resultant anti-frictional surface.

(10) VISCOSE RUBBER

Viscose rubber is a mixture of rubber and viscose used for waterproofing purposes. It is more economical than rubber alone and more desirable than rubber mixed with other substances.

(11) VISCOSE LEATHER

Viscose leather is leather treated with viscose cellulose to render it more pliable and waterproof.

(12) INSULATION PLATES

Cellulose in compressed form is used largely for plates in electrical insulation such as on switchboards, etc.

Under the second division where products are obtained after the cellulose solutions have been passed through a neutralizing bath into filament form we may consider the following:

- (1) Hollow Filament Yarn.
- (2) Rayon Waste.
- (3) Staple Fibers.

- (4) Artificial Wool.
- (5) Artificial Horsehair.
- (6) Artificial Straw.
- (7) Artificial Ribbon.
- (8) Delustered Rayon.

(1) HOLLOW FILAMENT YARN

Hollow Rayon filament known as "Celta" was developed in Switzerland. It is an aerated viscose product giving greater length for weight. In the manufacture of Celta the filament is similar to a pneumatic tire tube being inflated with air or gas. The filaments are then punctured or degassed after which operation they have the appearance of deflated pneumatic tubes. Under the microscope the filaments appear as hollow flattened tubes with a somewhat rough exterior and a smooth interior. The increase in surface of such filaments gives an increased covering power with greater softness and less luster than solid Rayon filaments. They are warm to the feel and the nearest approach to real net silk.

"Celta" is particularly suited for underwear and ladies' hose. It is widely used for pile fabrics such as velvets and plushes, also in men's ties, table covers, curtains and upholstery. Being generally lighter and finer than solid Rayon, more filaments can be assembled per denier hence its greater covering power. Tests made by the Associated Knit Underwear Manufacturers of America show 30 filaments in a 100-denier sample, 40 in a 150-denier and 42 in a 200-denier sample. Both the wet and dry strength of "Celta" yarn is slightly less than the average for solid rayon yarn.

(2) RAYON WASTE

Rayon waste consists of discarded material resulting from the production of Rayon yarns. Naturally there is a wide variation in quality, depending on the particular plant of

origin, and on the particular stage of manufacture from where the offal results. The best waste comes from the spinning and winding departments before the fiber has received any twist. This product is usually clean, soft and fluffy. Waste of this kind is used mostly in the Rayon top industry, for manufacture into spun and union yarns, which industry is the largest consumer. Reeling waste is not so desirable and must be garnetted before it can be used, since the waste at the reeling stage has a twist. American Rayon waste reaches the market in bales of about 450 pounds and in bags of about 150 pounds.

The various classes of waste may be defined as follows:

(a) *Spinning Waste* is made whenever material is spoiled through the breaking of distributors, the bursting of pipes or leakage arising from defective valves. It also includes waste made in piecing together broken ends.

(b) *Bobbin or Winding Waste* is material which has been cut from broken bobbins or from cylinders which have been subjected to shock by reason of rough handling while the material was in a wet condition. It also includes the extreme inner layer of yarn which is first wound on the bobbins and on which the perforations of the cylinder have been impressed.

(c) *Reeling Waste* consists of the defective portions of yarns broken in reeling and twisting, or those which become tangled in handling.

(d) *Soiled Waste* includes greasy yarn and that stained by traces of residue chemicals, adhering after faulty washing.

(e) *Mill Waste* comprises miscellaneous twisted waste occurring in all textile mills in the process of knitting, weaving or braiding Rayon yarn. This form of waste is negligible.

When a plant has just started a large amount of waste is produced, but as the operators become more skillful and the technical processes are better controlled the amount of waste decreases. The amount of waste produced differs also with

the different processes. In the Chardonnet, or nitro-cellulose, process the amount of waste is small because that obtained during the spinning operation can be re-dissolved in the spinning solution. The total average waste in a well-regulated plant manufacturing under this process runs about one-half of one per cent. There is no waste marketed in the acetate process because it can all be re-dissolved for spinning.

The amount of waste in the cupra-ammonium process is comparatively large because of the fact that the fibers do not receive their greatest strength until well toward the end of the process. Fair averages for soluble wastes from plants manufacturing by this process will run between three and one half and six per cent. None of the waste in the cupra-ammonium process can be reused in the manufacture. The principal source of Rayon waste is from the Viscose process for two reasons.

(1) At no stage in the Viscose process can any of the waste be used again in making up the spinning solution.

(2) The Viscose process is the one used in producing the great bulk of the world's supply of Rayon.

The average marketable amount of waste from a well-operated Viscose plant should be between two to four and one-half per cent.

In the beginning of the Rayon industry waste had no market so that it was either given away or destroyed. To American research belongs the credit for finding uses for this hitherto valueless product.

Its possibilities as a source of spun yarns were soon recognized and demand for waste at present exceeds supply. Partly manufactured Rayon waste comes to the market as slivers, noils and garnetted waste. These are briefly described as follows:

(a) *Slivers* or *tops* are the chief intermediate product

in the manufacture of Rayon waste into spun yarns. They are composed of long, straight, parallel filaments, resulting from the combing of high-grade untwisted waste into a soft, loose rope or strand of long fibres wound into balls, commercially known as tops. Tops of Rayon waste are produced in the same general way as in the worsted industry, but special equipment is required as well as experience in the technique of handling. In this stage of manufacture they correspond to tops in the worsted industry and to peigall in the spun-silk industry. They are used primarily for the production of spun Rayon yarn, for blending with worsteds in the production of hand-knitting yarns and in the weaving of lustrous fabrics.

In producing tops, Rayon waste is subjected to the operations of a number of cards, or more frequently of machines termed "gill boxes" or "preparers" which disentangle, open and mix the fibers of the waste. The fibers are thereby arranged in parallel order into a web-like sheet or layer which is combed to make the fibers equal in length by removing the short wavy filaments. The longer fibers resulting from the combing process, are condensed into a rope-like sliver which composes the tops.

(b) *Noils* consist of short fibers discarded by the comb in the production of tops. They are used as a blend with wool yarns for fabrics with sheen and luster such as silver-tones and bolivias, for which noils serve as an illuminant. They are also carded by commission yarn spinners and spun on the woolen yarn system.

(c) *Garnetted Waste* is produced from twisted Rayon waste. This hard thread waste cannot be used by the top manufacturer, but must be garnetted to make it useful for consumption. The process of garnetting consists in loosening up the original fibers by the action of saw-teeth machines. Garnetted waste is carded and worked on the woolen system and is used for the same purposes as wool shoddy.

(3) STAPLE FIBER

Staple fiber or spun Rayon has been produced for about 25 years. The first patent obtained was by Pellerin in France

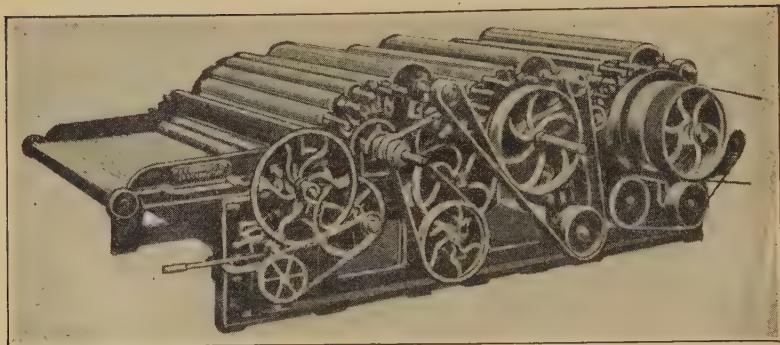


FIG. 6. "Garnett" Waste Opener with Three Shifts. (New Model.)

but his method proved unsuccessful. In 1910 Paul Girard of Lyons, France, obtained a patent on a method whereby the fibers were spun from a large number of nozzles, wound on bobbins and then cut on the bobbins so as to produce a mass of parallel threads of uniform length. In 1911 Messrs. F. & G. Mitchell of England obtained a patent on a method cutting Rayon into short lengths for spinning either by itself or with some other fiber.

The demand for Rayon staple fiber spun either by itself or with wool and cotton has become so enormous, and the amount of desirable Rayon waste being in no way sufficient to meet this demand, manufacturers of Rayon yarns are turning their attention more and more to the production of staple fiber. Staple fiber is made from either wood pulp or cotton linters. Its production closely follows that of Rayon yarn, in fact, the same spinning solutions can be used for both, but as the production of staple fiber does not need the accuracy, care and attention of the denier yarn the same careful preparation of the spinning solution need not be followed so closely. There is no necessity to secure the absolute uniformity required in the production of the yarn and as the winding, reeling, twist-

ing and other subsequent operations are eliminated the cost of production of staple fiber is considerably lower than for the yarn.

Staple fiber is produced by using spinnerets with many very fine holes, sometimes as many as one thousand to a spinneret, and after the filaments so exuded have passed through the neutralizing bath they are bunched together and cut off in lengths of from four to eight inches. It will readily be seen that staple fiber so produced is vastly superior for spinning either alone or with other textiles than Rayon waste, because in the latter the material is far from uniform, causing trouble and difficulty in the successive operations and especially in dyeing.

Staple fiber has been used mostly in combination with wool to produce worsteds in which the luster and beauty of the Rayon has enhanced the dullness of the wool. This combination is used extensively for pile fabrics, rugs, sweaters and hosiery. In conjunction with cotton the progress has been somewhat slower because of the difficulty in adapting cotton spinning machines to the more delicate fibers, but machines are now adapted to this purpose and it is safe to predict that the use of staple fiber of both cotton and Rayon will increase enormously.

Staple fiber has by itself been spun into yarn of fine counts but the best results have been obtained in conjunction with cotton, the mixtures ranging from 60 : 40 to 75 : 25. Staple fiber is produced under many different names, some of which are "Fibro," "Vestra," "Spinstro," "Surafel," etc. The production of staple fiber in the United States has been far behind that of Europe because it is extremely possible that considerably more staple fiber than denier yarn will be used in the future.

(4) ARTIFICIAL WOOL

Artificial wool is a variety of Rayon waste or staple fiber. It is made from short ends of very fine denier material combed, carded and spun into yarns in much the same way as sheep's wool. It resembles wool in appearance both in the raw and when made up into yarns and fabrics. It is lustrous and soft and combines well with natural wool, in fact it improves the appearance of the latter. It does not have the strength of wool either when wet or dry, but this is not a serious disadvantage as this property is not of vital concern in outergarments. It is moth proof and does not cause "itching." It is more transparent to ultra-violet rays than sheep's wool for which reason its hygienic effects are reputed to be desirable.

Artificial wool was first produced in Italy under the names of "Sniafil" and "Chatillaine." It is now being produced in France in increasingly large quantities.

(5) ARTIFICIAL HORSEHAIR

Artificial horsehair or "Crinol" is one of the earliest forms of Rayon. It is simply a Rayon thread of very heavy denier, that of the individual filament being 300 to 450. It is made either round or flat, depending on the shape of the orifice through which it is exuded. Its advantage lies in the fact that it can be produced in exceptionally long lengths and is therefore preferred for many uses to the natural product. The round form is used principally for braids and galloons and braided or woven hats. Other fanciful names have been given this product besides the name of Crinol by which it is generally known. Some of these names are "Meteor," "Turikum," "Helios," "Sirius."

(6) ARTIFICIAL STRAW

Artificial straw, also known as "Raffia," is produced by extrusion through a small slit. It resembles a silk-like straw and it has a lustrous crinkled surface. It is quite flexible and can be had in widths of from $1/3$ mm. up to 21 mm. It is also known in the trade as "Visca," "Lame," "Smoline," and "Rayon ribbon straw." Its principal use is in the millinery trades for braid straws and allovers. It is used alone and mixed with chip, hemp, metal and cotton. A number of companies are producing Rayon straw in Europe and in the United States.

(7) ARTIFICIAL RIBBON

Artificial ribbon is a flat filament of Rayon similar to artificial straw or "Raffia." It is used principally for platting, etc.

(8) DELUSTERED RAYON

Several brands of standard Rayon yarns are on the market from which the intense metallic luster, so undesirable in Rayon, is lacking. These delustered yarns are produced usually by treating cellulose solutions with various salts of acids which produce a yarn with a dull luster.

In the United States two of the largest producers of Rayon yarn have recently placed these delustered yarns upon the market. The Viscose Co. in describing their new "Dulesco" yarns state that the characteristic is a less degree of luster than their regular yarns and that this degree of luster is permanent. One of the officials of the company said "As to its marketability, we expect it to supersede in a large number of cases the more lustrous yarns, but so far it has been produced such a short time that we feel the market is only in the first stages and we are not in a position to tell

just how the production of this will be as compared with the more lustrous yarns heretofore produced."

The DuPont Rayon Co., Inc., in announcing its new "Lolustra" yarn says, "In order to meet the requirements for certain types of fabrics which call for a yarn having a luster of a less degree than the present standard yarns, DuPont Rayon Co., Inc., is placing its new 'Lolustra' yarn on the market.

"The new yarn, which will supplement the present Standard Rayon yarn and the Super-Extra (multi-filament) types has a luster of about the same degree of brightness as silk. This subdued luster is not obtained by an after-treatment of the yarn but is, on the contrary, an inherent and permanent characteristic accomplished in the manufacturing process itself."

The above are some of the already developed channels which have been opened up by the increased use of Rayon but of the many more which will be opened up, many of which are advanced as far as the laboratory stage, no man can tell.

CHAPTER V

FINANCIAL

THE public is looking in amazement at the stupendous figures being given out, from time to time as to the constantly increasing production and profits, by some of the companies manufacturing Rayon. The Samuel Courtauld & Co., Ltd. of England with its subsidiary, the Viscose Company of America, the Tubize Artificial Silk Company, The Celanese Corporation of America, and a few other European concerns had, for twenty years, kept to themselves the knowledge that the Rayon industry was not only a profitable one but that it had surpassed, in financial returns, the dreams of the most fanciful money maker.

In carrying out the work of developing their industry these companies have not broadcast the results as most other industries have done, but in a very passive way have preserved to themselves the knowledge of the immense commercial possibilities of Rayon. When the information reached the public ear, however, the exuberance that comes with anything that is new, found no bounds. The surprising fact is how the few operating companies kept their secrets so well. It has not been so with other industries. When the Radio craze came into being it took less than two years to bring about the birth of some three thousand factories producing Radio sets and parts.

New industries, once reaching the public attention, usually start with a bang; the Rayon industry, principally due to technical reasons, did not at first go with the same spon-

taneity. With the processes and technique of this industry almost totally controlled in Europe, there was no way to initiate any great number of Rayon companies. All the plants which have made a success have been those which were initiated by European Rayon producers. Their knowledge of the great possibilities of this unique industry, even when launched in the United States, was such that even the capital was of European origin. At this writing, eighteen years since the industry was first introduced in this country, European capital was still forcing itself within the financial structure of the American Rayon companies. The most recent instance being the Dutch Enka who have financed in Europe practically all of the \$24,000,000 capital for the American Enka Company, before it was even known where the plant was to be located. Europe is all alive to the possibilities of this enterprise in the American market, while only a small handful of people realize it in America. The knowledge of the processes was held by interests in Europe. Fortunately, there were no Rayon technicians in the United States and hence few American originations, in any event not a great enough number to worry the country. Because of the few originations and since the shares of the American companies were supported abroad, a demand for Rayon shares commenced to be created in the United States.

And so when Samuel Courtauld & Co., Ltd. of England announced that they would let the public buy shares which originally were sold to the insiders at one pound per share, at something like thirty-four shillings, the whole story had to come out. Everyone, promoter, banker, engineer, manufacturer and the man in the street talked of Rayon. They spoke of it in terms of familiarity. Each one had a different story to tell, so that the true history of this industrial youngster was twisted into many phases and forms and at this writing all of the banks and bankers, the textile and silk journals,

the textile and silk manufacturers, the dyers, investment journals and houses—all are building facts and figures. Even the daily papers scarcely pass a single day without the mention of Rayon.

Every city in the United States, particularly those in the South, recognizes the importance of Rayon manufacture and many pages of advertising appear in trade journals encouraging the construction of plants for Rayon production in the cities.

At this point let us briefly review the early financial struggles of the Rayon industry on this continent. The technical and the financial side of the struggle are closely interwoven, but in so far as possible we shall confine our immediate interest to the financial side. In 1904 just a little over 20 years ago there was held in Philadelphia the Lansdowne sale. This was a receiver's sale in bankruptcy. It marked the end of the first attempt at Rayon production in America and at this sale, patents, controlling the production of Viscose silk, were sold for \$2500. The ownership of those patents has brought the succeeding company (The Viscose Company of America, owned almost entirely by Courtaulds, Ltd. of England) a fortune beyond the dreams of the promoters of the original venture that failed. Since then The Viscose Company of America has become a phenomenal success, and in the short space of some ten or more years Du Pont Rayon Company, Tubize Artificial Silk Company of America, Industrial Rayon Corporation, The Celanese Corporation of America, the American Bemberg Corporation and others have come along and are also successes. With the years has come a broadening of Rayon markets, brought about by improvements in quality and manufacturing processes, so that the whole picture is an inter-related and cumulative one. Today the demand for Rayon is always increasing and the cotton manufacturers, as larger and larger users of Rayon, are

becoming interested prospects for entering the field of Rayon production.

The problems of Rayon making were at first purely chemical and it was the chemical expert who first understood and interpreted the industry. While problems that confront the producer are still largely chemical, the mechanical and managerial phases are coming to the front, and it requires an association of experts in these three phases successfully to launch a Rayon plant. We mention this here merely to show that it requires something more than mere enthusiasm to develop a Rayon project.

There never was a day when a group of bankers, promoters or business men, technically untrained, could take an interesting laboratory demonstration and make an earning Rayon company out of it. Such a project must be approached with all due caution. Only in two or three instances have chemist demonstrators attracted sufficient capital to make a slightly better start than a mere laboratory gesture. And lacking the necessary experience and ability for large scale financing, they knew nothing of maintaining interest to the point where such efforts meant operation on a larger scale. It is an unfortunate fact that the industry presents difficulties when production of Rayon is on a small scale.

More unfortunate is that phase of endeavor for developing the industry which arose from the fact that no known set of figures existed to indicate the size of plant which, when built, would earn money. Nor was it known what total capital was needed to build and operate a profitable plant. In 1920 the author prepared a chart which showed for the first time that it took one million dollars of capital at that time for every 1000 pounds of Rayon produced daily. While this figure still applies for very small plants it is considerably less for those of large output. One thousand pounds produced per day of 24 hours would have shown a profit in 1920 due

to the then prevailing high prices of Rayon. It takes at least 3000 pounds per day of 24 hours, in a plant properly designed, equipped and managed, to show a profit at the present time. This does not apply to the Rayon yarns which command high prices such as the cupra-ammonium and the cellulose acetate processes.

In 1920 (and always since), the author has repeatedly stated that large capital, and experience in the technical phases of the enterprise and in personal organization, are essential and important. Completing a Rayon plant is not sufficient. Months of labor must be assigned to co-ordinating all of the factors, in order to put such a plant on an earning basis. Hundreds of thousands of dollars are required in order to get the plant set for continuous production after completion. No other industry presents parallel conditions. Once you organize a watch plant, or automobile plant, production can begin almost on a predetermined set scale. It is not so with Rayon. After the completion of the plant at least eight months must be given to bringing it up to production at a cost which represents a part of the capital investment, a phase quite different and which does not exist in any other industry.

There were a few attempts made to start Rayon companies of strictly American origination by workers who, having held limited positions in various Rayon plants here or abroad, and with a limited knowledge of plant layout and operation, succeeded more often than not in getting enough money together to start a small unit which as a rule could not reach the point of profitable production.

The American-operated Rayon plants, as already stated, started entirely with a technical and financial European background, whereby they simply copied the success obtained abroad as to production for no concern was ever had as to the disposal of the product.

In recent years, since it became so evident that the Rayon

industry is so profitable, Americans representing capital went abroad and paid well for the talent, knowledge and experience to some of the European Rayon producing companies who were given "carte blanche" to reproduce in the United States the European Rayon engineering practice. It meant paying considerable tribute for such European association and co-operation. This procedure gave the infant industry in the United States such an impetus in Rayon production that today we are the largest producing country in the world. A time has now been reached where the United States has developed its own Rayon technical talent and the industry which had to rest almost entirely upon European indulgence, at so great a cost, will from now on be enabled through distinctly American talent to keep the large profits in this country for further development and expansion.

At present the whole country is awake to this great industry, largely because of the free newspaper and magazine publicity which has helped to bring to the public's attention the large earnings of almost every Rayon company. When one considers that Courtaulds, Ltd. of England started in 1913 with only a few million dollars capital and has piled up assets, out of earnings, running into hundreds of millions of dollars, and that Tubize, with a capital of only a few million dollars, has earned enough to liquidate its bonded indebtedness and retire most of its preferred stock so that nearly all earnings are computed for the common shares only—one realizes why these shares grow more valuable as time goes on.

With such astounding facts before us and with other evidences of great possibilities, due to the constant increase in demand, it will not be difficult to obtain all the financing of the future Rayon plants, of which there will be many more, in the United States.

It is appropriate to state here that while the European capital invested in American Rayon plants draws its annual

profits the European technical experience which has been employed for the development of existing American plants are also drawing tribute which runs into many millions of dollars annually. This technical experience is represented by shares of stock which these foreign companies have received from the American companies as compensation for their knowledge and technical co-operation. Some millions of dollars is paid to Europe for this initial piece of work. The time is fast approaching when such tribute need not be increased or continued.

In the following pages are given the financial structure, statements and dividend history of some of the leading Rayon producers.

The **Viscose Company of America** is capitalized as follows:

\$37,784,000	7% Preferred stock
\$47,230,500	Common stock

Eighty-five per cent of this stock is owned by the Controlling Company, Courtaulds, Limited, of Coventry and Braine-tree, England. It is noted that a small percentage of the capital stock of this corporation is held in the United States, and that only by its officers and the managerial staff. The American public has never been given the opportunity to participate in the immense profits this company has been earning, and paying to the Courtaulds in England. In order to know to what extent the Courtaulds profited from this American Company, its entire fiscal status will be discussed immediately after this. The American public has, through Brown Bros., the international bankers, been given the opportunity to invest in Courtaulds' American Shares, that is, the Brown Bros. having bought a block of British Courtaulds' shares for their account, placed these in Trust and issued American shares to cover the original English shares and these American Courtaulds' shares were then offered to the American public.

The Courtaulds, Ltd., is capitalized as follows:

\$38,980,000	5% Preferred stock
\$58,320,000	Ordinary shares

The shares are in one-pound denominations. Profits, dividends and reserves over a period of twelve years are shown in the following table:

TABLE 31: COMPANY PROFITS, DIVIDENDS AND RESERVES.

Year Ended Dec. 31	Net Profit	Per Cent	Dividend Amount	Appropriated to Reserves
1913	\$2,061,383	7½	\$729,000	\$1,003,512
1914	2,528,896	12½	1,215,000	972,000
1915	3,604,501	20	1,944,000	972,000
1916	5,267,865	30	2,916,000	2,418,775
1917	5,690,389	30	2,916,000	4,429,027
1918	5,758,798	32½†	3,159,000	2,185,347
1919	11,084,984	30*	5,832,000	4,859,965
1920	8,771,300	11¼*	7,047,000	972,000
1921	10,374,122	11¼*	6,561,000	3,645,000
1922	17,342,579	15*	8,748,000	7,533,000
1923	16,120,377	15*	8,748,000	6,802,000
1924	22,019,410	20*	11,664,000	8,019,000
1925	21,439,467	25		
1927	22,389,595	25†	16,224,000	4,860,000

These figures are converted from pounds at the exchange rate of 4.86.

* Free of tax.

† 17½% of which is free of tax.

December, 1919, Capital Bonus 100 per cent.

November, 1920, Capital Bonus 200 per cent.

June 1924, Capital Bonus 66⅔ per cent.

March, 1928, Capital Bonus 100 per cent.

The consolidated balance sheets of Courtaulds, Ltd., as of December 31, 1923 and 1924, compare as follows:

Assets:	<i>Dec. 31, 1923</i>	<i>Dec. 31, 1924</i>	<i>Dec. 31, 1925</i>	<i>Dec. 31, 1927</i>
Fixed assets.....	\$11,196,191	\$11,866,176	\$20,892,949	\$27,723,361
Inventories	5,887,890	6,148,255	7,512,720	9,224,575
Interest in The Viscose Company.....	37,927,440	77,826,237	77,842,714	116,493,261
British Govern't and other investments..	35,882,605	45,005,208	49,654,069	45,635,594
Debtors	3,234,102	3,872,895	3,862,717	6,227,643
Cash	8,000,563	10,608,758	10,521,815	16,967,099
	\$102,218,791	\$158,327,529	\$170,286,984	\$222,271,533
Liabilities:				
Issued capital... ..	\$58,320,000	\$97,200,000	\$97,200,000	\$97,200,000
Creditors and Dividend Payable.....	23,711,035	30,537,713	23,736,728	17,665,793
Reserves	16,524,000	25,561,689	34,060,663	90,868,295
Carry forward Surplus P & L account	3,663,706	5,028,127	15,289,593	16,537,445
	\$102,218,791	\$158,327,529	\$170,286,984	\$222,271,533

The present value of Courtaulds shares, as quoted on the London Stock Exchange, is about £9 (\$43.75). Transferable certificates or deposit trust receipts are quoted in the United States between \$33 and \$34. Courtaulds' 1927 statement of earnings shows net profits of \$22,389,595 and the last dividend declared brought the total for the year up to 125 per cent, 25 per cent of which was in cash and 100 per cent in stock. As a more complete document of interest the report of the directors of this British company, which owns 85 per cent of the American Viscose Company, is given herewith:

The Directors beg to submit their Report and the Accounts for the year ended 31st December, 1927.

After charging Depreciation of Buildings, Plant, Stocks-in-Trade and Investments, Directors' Fees, Income Tax, and all expenses of management, and after carrying the sum of £250,000 to Special Reserve for depreciation of Plant and Buildings, the Profits of the year amount to £4,585,921 7s. 9d.

To this sum must be added £1,036,797 19s. 0d. brought forward from 1926, making together £5,622,719 6s. 9d.

An interim Dividend on the Ordinary Shares for 1927 has already been paid, absorbing £900,000, and the Dividend on the Preference Shares for 1927 has absorbed £400,000, and the Di-

rectors have decided to place to General Reserve Account the sum of £1,000,000.

The available balance is, therefore, £3,322,719 6s. 9d., and the Directors recommend that a Final Dividend of 3s. 6d. per Share, free of Income Tax, amounting to £2,100,000, be declared for the year ended 31st December, 1927, that £1,222,719 6s. 9d. be carried forward, and that the Dividend be paid on the 12th day of March, 1928.

The hopes of improving business which we expressed twelve months ago have been in the main realised.

The chief exception relates to our weaving branch, which has had to contend with the depression from which English weavers in general are suffering. The present outlook is somewhat brighter.

We have sold a largely increased weight of artificial silk in England at the price level established by the reductions made in July, 1926. Stocks are low, and the immediate outlook is favourable.

The American Viscose Corporation also reports largely increased sales as compared with the previous year at prices somewhat above the lowest point reached in November, 1926. The position and outlook in the United States are much the same as in England.

At Wolverhampton, we reached full production in July last, and at the same time it was decided to duplicate this factory. The new unit is expected to start producing in the early Autumn.

The Canadian factory has been running at full capacity throughout the year, and an extension which was put in hand during the summer is just coming into operation.

La Soie Artificielle de Calais, S.A., started working in the Autumn. The production of this Company's factory has now reached about one-third of full capacity, and is steadily increasing.

The Cologne factory of Glanzstoff-Courtaulds, G.m.b.H., is also beginning to come into operation.

The Directors have placed a value of £18,557,248 10s. 7d. upon the Shares held by the Company in the American Viscose Corporation, and have carried the additional value thus shown, amounting to £8,251,191 16s. 4d., to the credit of Capital Reserve Account, together with the surplus realised on the disposal

of Preferred Stock of that Corporation, amounting to £669,865 8s. 3d., making, with the amount of £210,641 4s. 4d. already standing to the credit of that Account, a total of £9,131,698 8s. 11d.

They have also decided to recommend to the Shareholders that the total Capital of the Company be increased to £32,000,000 by the issue of 12,000,000 new Ordinary Shares of £1 each, and that £9,000,000 of the amount standing to the credit of Capital Reserve Account, together with £3,000,000 of the amount standing to the credit of General Reserve Account, making a total of £12,000,000, be capitalised and be applied in making payment in full at par for the said new Ordinary Shares and that such new Ordinary Shares be distributed among the Holders of the existing Ordinary Shares in the Company at this date, at the rate of one fully paid new Ordinary Share in respect of each existing Ordinary Share of the Company held by such Shareholders respectively. The Resolutions to be submitted to the Shareholders accompany this Report.

The Directors wish it to be understood that this recommendation is made in order that the Share Capital of the Company may more nearly represent its actual assets, and that this proposed increase of Capital does not necessarily imply any increase in the total amount of profit to be distributed in the future, which must always depend upon earnings.

The Board, under the powers contained in the Company's Articles, appointed on the 21st April, 1927, Mr. Ernest Lunge, a Director, and the Board now propose that at the forthcoming Meeting of the Shareholders he be elected a Director of the Company.

The retiring Directors are Mr. S. A. Courtauld, Sir T. P. Latham and Mr. F. Johnson, who are eligible and offer themselves for re-election.

The Auditors, Messrs. W. Elles-Hill & Co. and Messrs. Price, Waterhouse & Co., also offer themselves for re-election.

SAMUEL COURTAULD, *Chairman.*
E. KETTLE, *Secretary.*

16 ST. MARTIN'S-LE-GRAND,
LONDON, E.C.1.

21st February, 1928.

The directors of Courtaulds, Limited, are the following:

SAMUEL COURTAULD, 20 Portman Square, W.1, *Chairman*.

STANLEY BOURNE, Epperstone Manor, Nottingham, *Deputy Chairman*.

SAMUEL AUGUSTINE COURTAULD, The Howe, Halstead, Essex.

SIR THOMAS PAUL LATHAM, Bart., Crow Clump, Weybridge.

FREDERICK JOHN NETTLEFOLD, 1 Cambridge Gate, N.W.1.

JAMES STANLEY ADDISON, Wethersfield Place, Braintree, Essex.

FREDERICK JOHNSON, The Mount, Davenport Road, Coventry.

ERNEST LUNGE, 40A Hyde Park Gate, S.W.7.

HENRY JOHNSON, Highfield, Coventry, *Managing Director*.

GEORGE JAMES BELL, Sewardstonebury, Essex, *Managing Director*.

Following the announcement of this report there appeared an article in the *New York Times* of Feb. 23, 1928, which gives a true picture of the public's new interest in Rayon securities.

The Old Lady of Threadneedle Street, as the Bank of England is called, had a front row seat today at the most spectacular trading performance in artificial silk shares on the Stock Exchange which the commercial world has ever experienced. The fun began almost before the "Old Lady" had properly finished her breakfast, wiped her spectacles and opened her place of business.

The overnight announcement of a \$60,000,000 bonus for shareholders of Courtaulds, Ltd., artificial silk makers, was the cause of the excitement.

The Stock Exchange is just across the street from the Bank of England. The wedge-shaped quarter acre space in front of the Exchange Building was thronged with brokers, clerks and assistants long before 9 o'clock, which is the official hour. There was so many excited men yelling and calling, wigwagging with hands and arms, making faces and indulging in other contortions that the stenographers, telephone girls, typists and the thousands of other young women employed in the financial district had fairly to fight their way through the crowds to their offices.

Dealing in Courtaulds' stock actually started half an hour

before the Exchange opened. As time passed, the crowd was increased by interested persons who came from all directions, and the babel of conversation, shouts and yells became more intense. The crowd swarmed like bees around new honey. Practically every broker of the financial district had clients interested in Courtaulds and as soon as these clients had read the news in the morning papers they hurried to the city to consult their brokers and participate in the excitement.

The shares, which closed yesterday at £7 11s 16d, rose today to £9 5s. They afterward fell back slightly, but then climbed again while the brokers scrambled, dodged and wriggled through and around the seething mass endeavoring to reach a nearer position. In a few moments after the Exchange opened, the shares had shot up to £9—in other words, the total market value of the ordinary shares had risen more than \$65,000,000 in about ten minutes. The excitement spread like wildfire and affected all other sections of the artificial silk market.

The history of Courtaulds, Ltd., is one of the most dramatic industrial developments since the World War. It is estimated that the company now controls 80 per cent of the world's artificial silk trade. It was organized in 1913 with a capital of only £2,500,000 which has now grown to £32,000,000 without any new subscriptions. The dividend this year was at the rate of 25 per cent.

The fact that the New York Exchange was closed today in observance of Washington's Birthday prevented buying and selling orders from the other side, but, as it was, today's scenes were among the wildest in the history of the Old Lady of Threadneedle Street, who has been on the job in the same place for 234 years. Habitues of the Exchange found a parallel only in the great Kaffir boom in the '90s.

The Du Pont Rayon Company is a close corporation and its stocks are not available to the public. It is capitalized at 100,000 shares no par value common stock, all of which is owned by E. I. Du Pont de Nemours & Co. and their affiliated interests. No balance sheets are available to show the financial strength of this unit. However, in plant and production this company has shown a steady increase so that the

Rayon business now represents about one-eighth of the Du Pont total.

The **Tubize Artificial Silk Company** whose plant is at Hopewell, Va., was incorporated in Delaware on March 3, 1920, and began the manufacture of artificial silk in the summer of 1921, using on a royalty basis the patents and processes of the Fabrique de Soie Artificielle de Tubize, an old established Belgian company with a long record of successful operation. The process used is known as the Chardonnet process, so named after its French discoverer, Count Hilaire de Chardonnet, who patented this method in 1884. During the first years of operation the Tubize Artificial Silk Company of America enjoyed close working relations with the Belgian company, for in addition to the royalty arrangement the latter had a substantial stock interest in the American company. Practically all of this stock, however, was later secured by American interests, and the royalty agreement was terminated, the rights to the Belgian patents and processes being purchased outright by the American concern. This has resulted in a substantial saving to the latter.

The Company is capitalized as follows:

The Company has no funded debt and its policy has been to keep itself free from bank indebtedness. Its present capitalization consists of:

	<i>Authorized</i>	<i>Outstanding</i>
6% Cumulative Preferred Stock (par \$100)	\$5,000,000	\$2,500,000
Class "A" Common Stock (no par value)	20,000 shares	20,000 shares
Class "B" Common Stock (no par value)	80,000 shares	78,868 shares

The Preferred Stock is callable as a whole only on or after July 1, 1930, at 110 and accrued dividends and is entitled to 110 and accrued dividends in liquidation.

The Class "A" and Class "B" Common Stocks are identical in all respects except that Class "B" has the right to elect a majority of the Board of Directors. All of the Class "B" and

part of the Class "A" Stock is held in a 10-year voting trust which expires December 15, 1933.

EARNINGS

While it has not been the Company's policy to publish financial statements, earnings reported officially for 1925 and 1922, and estimated on the basis of Federal income tax returns as to 1924 and 1923, have been:

	<i>Net Income after all charges</i>	<i>Earnings per share on Common based on present stock capitalization</i>
*1922.....	\$1,400,000	\$13.25
1923.....	2,900,000	27.85
1924.....	1,600,000	14.85
1925.....	3,300,000	32.00

Despite the late Summer and Fall depression in the artificial silk industry in 1926, the Company is estimated to have earned at least \$20 per share of Common Stock on the basis of its present stock capitalization. Since it is reported to be the Company's present policy to distribute not more than one-half its annual earnings in the form of dividends, the action of the management in placing the Common Stock on a \$10 annual dividend basis this year tends to confirm this estimate.

FINANCIAL

The Company enjoys an excellent financial position, with working capital ample for its needs. Cash and Government securities at the present time are reported to amount to over \$3,000,000, while current liabilities include only current accounts, there being no bank loans.

Since organization the Company has retired securities senior to the Common Stock to an amount of over \$4,500,000, substituted a 6% Preferred Stock issue for the remainder of the original 8% Preferred Stock outstanding, and has financed additions and improvements to the plant and property that have resulted in an expansion of output from approximately 3,500,000 pounds annually to about 8,000,000 pounds annually. This had been ac-

* First full year of operation.

complished out of earnings and without impairment of the Company's financial position.

DIVIDENDS

The Company inaugurated dividends on the Common Stock at the rate of \$10 per share annually with the payment of an initial quarterly dividend of \$2.50 per share on July 1, 1927. It is understood the Company's policy for the present will be to pay out in dividends not more than one-half its annual earnings.

MARKET

The Common Class "B" Stock (voting trust certificates) is traded in on the New York Curb Market and has ranged in price as follows:

<i>Year</i>	<i>High</i>	<i>Low</i>
1925.....	270	147
1926.....	240	153
1927.....	304	145
1928 to June 1.....	680	490

MANAGEMENT

The management of the Company is highly regarded in trade and banking quarters. The officers and directors of the Company are as follows:

ROLAND L. TAYLOR, *Chairman*, of Dillon, Read & Co., Philadelphia, Pa.

WALTER L. COURSEN, *President and Director*, formerly general production manager of the New Jersey Zinc Co.

EDWARD V. PETERS, *Vice-President and Director*, formerly general sales manager of the New Jersey Zinc Co.

GORDON A. HARDWICK, *Vice-President and Secretary-Treasurer*, Philadelphia, Pa.

JOHN ANDERSON, *Director*, Chairman, Charles Pfizer & Co., Inc., New York.

COL. W. P. BARBA, *Director*, Philadelphia, Pa.

LEDYARD HECKSHER, *Director*, Philadelphia, Pa.

WILLIAM LLOYD KITCHEL, *Director*, of Cadwalader, Wickersham & Taft, New York.

JOHN W. METTLER, *Director*, Pres., Interwoven Stocking Co., East Millstone, N. J.

RUFUS W. SCOTT, *Director*, of Rufus W. Scott Co., New York.

E. R. WOOD, *Director*, Pres., Dominion Securities Corporation, Ltd., Toronto, Canada.

The **Industrial Rayon Corporation** was formed to acquire the controlling interest in the Industrial Fibre Corporation, formerly owned by Italian interests, consisting principally of the Unione Italiana Fabbrica Viscosa, Banca Agricola Italiana and Snia Viscosa (Societe Nazionale Industria Applicazioni Viscosa). This was accomplished through a syndicate formed by Walter W. Birge and Samuel Ungerleider.

The capital structure consisted of Class "A" and Class "B," no par value common stock. The Class "B" stock carries voting power and was issued to the management group with Mr. Walter W. Birge as President of the Corporation. Mr. Birge served as President until May, 1926, when Mr. Bertrand R. Clarke, for several years Vice-President of Tubize Artificial Silk Company of America, was elected President of the Industrial Rayon Corporation. In explaining the plans of the corporation, Mr. Clarke, stated after his election to the Presidency:

"It is the plan of the new management to acquire all of the outstanding securities of its present subsidiaries—the Industrial Fibre Corp. of America, the Industrial Fibre Throwing and Dyeing Co., so that there will be but one large company.

"The owners of Class 'B' stock have agreed to exchange their holdings, share for share, for Class 'A' stock, thus leaving only one class which will have full voting rights."

After the aforementioned changes took effect the results reflected favorably in the affairs of the Company. The author is confident that this organization will in time take its proper place among the foremost Rayon producers. Increased production should be the immediate aim.

THE RAYON INDUSTRY

These classes of stock authorized and outstanding are as follows:

<i>Stock</i>	<i>Authorized Shares</i>	<i>Outstanding Shares</i>
Class "A"	598,000 non-voting	425,000
Class "B"	2,000 voting	2,000

This Class "A" stock was offered to the public at \$20 per share. Table 31A shows comparative statement of earnings and expenses of the Industrial Rayon Corporation at the time the public stock offering was made.

TABLE 32: INDUSTRIAL RAYON CORPORATION'S COMPARATIVE STATEMENT.

	6 Mos. Ended June 30, 1925	Year Ended Dec. 31, 1924	Year Ended Dec. 31, 1923	Year Ended Dec. 31, 1922
Gross sales	\$2,056,991.70	\$3,278,174.31	\$2,156,175.40	\$1,492,903.65
Less cost of goods sold, transportation, discounts, etc.	1,344,925.11	2,404,213.78	1,355,632.24	835,692.90
Gross profits from sales	\$712,066.59	\$873,960.53	\$800,543.16	\$657,210.75
Less expenses, taxes and depreciation..	162,112.23	459,779.81	362,745.59	325,623.12
Net profit	\$549,954.36	\$414,180.72	\$437,797.57	\$331,587.63
Other income	6,478.61	18,169.91	10,756.67	12,355.29
Net earnings	\$556,432.97	\$432,350.63	\$448,554.24	\$343,942.92
Deductions for inter- est on funded debt and amorti- zation of discount on notes	59,415.50	126,801.57	131,946.53	104,079.57
Balance	\$497,017.47	\$305,549.06	\$316,607.71	\$239,863.35

Industrial Rayon stock was quoted on the New York Curb Exchange in May, 1926, at about \$13¼ per share. Its

high mark quotation for 1926 was \$19 $\frac{7}{8}$ and at the time of this writing the average quotation is approximately \$16 per share.

All of the above, regarding the Industrial Rayon Corporation, was written in the first edition of this book towards the end of 1926. For a clear comparison of what actually took place since then in the career of this corporation and since it is the one company the securities of which are so widely distributed among the American public, the author deems it proper to append the entire report of its president for the year ending December, 1927.

EARNINGS

Following are extracts of this company:

We show a net profit for 1927 of \$907,768.73, after provision for estimated Federal Income Tax, of which amount \$269,270.00 was earned during the first six months of that year, and \$638,498.73 was earned during the last six months period.

The increase in earnings in the last six months period was due substantially to four outstanding factors, viz.:

1. Further reduction of manufacturing cost.
2. Reduced administrative and selling expense.
3. Increase in average selling price resulting from improved quality and greater production in the higher grades.
4. No carry-over of low-priced sales contracts such as we experienced in the prior period.

Many other items contributed to increased earnings, but the market price of Rayon remained unchanged and should be excluded as a factor.

ADDITIONS TO BUILDINGS AND EQUIPMENT

Our new office building and extension to plant and equipment were completed during the last six months of 1927, and are now in use and operation.

THE RAYON INDUSTRY

The 1927 capacity of our plant, amounting to approximately 3,500,000 pounds, has been increased to 4,250,000 pounds for 1928.

Our executive, engineering and clerical staffs, formerly located at various points throughout the plant, are now housed in an office building under one roof, where our business is being handled more economically and efficiently.

\$355,051.35 was spent during 1927 for new buildings and additional equipment, exclusive of repairs, and we are pleased to report that our plant is now in excellent condition and should require no unusual expenditures for maintenance during the ensuing year.

FINANCIAL CONDITION

We continued with no bank loans in the second half of 1927, and were able to maintain a substantial bank balance.

During the same period, we retired all of our first mortgage bonds, amounting, with premiums, to \$269,750.00. We also retired debentures in the amount of \$136,800.00; all of our first preferred stock amounting to \$76,200.00; and second preferred stock—\$123,200.00—a total of \$605,950.00—and withal, we finished the year 1927 with an improved current position.

ORGANIZATION

There has been no important change in the personnel of our organization since our semi-annual report of June 30th, 1927.

A gradual improvement in morale has been noted. Our new sales policy of direct representation to the trade has received favorable comment from our customers, and has developed a better understanding of their needs, which in turn has enabled us to serve them more satisfactorily in every way. Co-operation is on the uptrend in every department of our business.

FUMES CASE

In this case the Common Pleas Court found the company guilty of maintaining a nuisance and assessed a fine of \$25 and ordered an abatement of the nuisance on or before January 1st, 1928, a six months period.

We carried the case to the Court of Appeals on error, and on March 16th, 1928, the Court of Appeals, composed of Judges Sullivan, Levine and Vickery, handed down a decision reversing the holding of the lower court on the ground that the verdict was contrary to the weight of the evidence and contrary to law, and remanded the case to the lower court for re-trial.

The Court of Appeals, in its decision given by Judge Vickery, held that inasmuch as the plant was located at its present location in 1917, and that at such time in view of the fact that it was located in what is considered an industrial neighborhood along the railroad, and in view of the fact that at the time of its erection there were within a radius of half a mile only two homes, the company acquired certain rights as predecessor, and that the building of the homes within this territory was altogether at the neighbors' risk and peril, as they must accept conditions in an industrial neighborhood with the inconvenience of noise, odors, smoke and fumes; that so long as it appears that the company has used the most modern appliances and machinery and that there is no known means of elimination, it would work an injustice to close the plant.

The opinion establishes new law in this State, and inasmuch as upon all the evidence offered by the State the Court of Appeals finds that the evidence is not sufficient, unless the State has something substantial to add to the former case, in the opinion of our counsel a further trial of this case on the part of the State would, in the light of the Court's decision, be futile.

NEW CORPORATE SET-UP

By proper corporate action Industrial Rayon Corporation has acquired all of the assets of Industrial Fibre Corporation of America and of The Industrial Fibre Company, Inc. For your information there is enclosed herewith a copy of a letter sent by Industrial Fibre Corporation of America to the holders of the small minority of No-par Common Stock of said Company not owned by Industrial Rayon Corporation. The First Mortgage Bonds, First Preferred Stock and Second Preferred Stock hereinbefore referred to as having been fully retired and the Debentures referred to as having been partially retired, were outstanding securities of Industrial Fibre Corporation of

America. We are glad to advise you that a very large proportion of said outstanding minority stock elected to exchange their stock for Class "A" Industrial Rayon Corporation Stock, there being outstanding at present only 2,792½ shares of said Industrial Fibre Corporation of America Stock which is exchangeable for Industrial Rayon Corporation Class "A" Stock or payment on the basis of \$7.50 per share. The retirement of stocks, bonds and debentures before referred to and the acquirement of the assets of Industrial Fibre Corporation of America greatly simplify the corporate structure of Industrial Rayon Corporation.

INDUSTRIAL FIBRE CORPORATION OF AMERICA

Cleveland, Ohio, January 3d, 1928.

*To the Stockholders of
Industrial Fibre Corporation of America:*

Pursuant to action of your Board of Directors and the consent of the holders of more than ninety-five per cent of the Common stock, a sale of the assets of Industrial Fibre Corporation of America to Industrial Rayon Corporation has been agreed upon, whereby Industrial Rayon Corporation assumes all of the obligations of the Fibre Corporation, surrenders all Fibre Corporation's First Preferred stock, and will pay to the common stockholders of Fibre Corporation, Seven and 50/100 Dollars (\$7.50) per share, or deliver, at the stockholder's option, one-half of one share of Industrial Rayon Corporation Class "A" stock for each share of Fibre Corporation's Common stock.

This corporation and subsidiary is indebted to Industrial Rayon Corporation in large amounts, and Industrial Rayon Corporation holds all of the now outstanding First Preferred stock.

The First Preferred stock provides that no dividends shall be paid on the Common stock so long as any of the First Preferred stock is outstanding. This would require the retirement of prior charges out of profits to the extent of approximately \$2,000,000, or an expensive refinancing, before distribution of profits could properly be made to the holders of Common stock of the Fibre Corporation. By the sale of the assets to Rayon Corporation, Fibre Corporation Preferred stock is surrendered

and the debt to Rayon Corporation is cancelled, thus putting Industrial Rayon Corporation in a position to distribute such of its surplus earnings as its Directors may deem advisable.

All but less than five per cent of the present Common stock of Fibre Corporation has been previously exchanged for Industrial Rayon Corporation stock in the proportion of one-half share of Rayon Class "A" stock for one share of Industrial Fibre Corporation stock, and the sale of the assets provides for this exchange, at the stockholder's option. Any stockholders who do not wish to transfer their holdings into Rayon Corporation Class "A" stock are entitled to cash at the rate of \$7.50 per share.

Contemporaneously with the acquisition by Industrial Rayon Corporation of the assets of Fibre Corporation, all of the Class "B" stock of Industrial Rayon Corporation will be placed under a Voting Trust Agreement for a period of five years, subject to extension for a further period of five years upon the vote of the holders of a majority in interest of the Voting Trust Certificates, and subject to termination at any time upon the vote of a majority of the Voting Trustees.

The Voting Trustees will be F. A. Aldrich of Flint, Michigan, Henry A. Beckerman of Cleveland, Ohio, Lawrence Chamberlin of New York, N. Y., W. C. Durant of New York, N. Y., J. Arthur House of Cleveland, Ohio, Hiram S. Rivitz of Cleveland, Ohio, and Samuel Ungerleider of New York, N. Y., all of whom own or represent the owners of substantial amounts of Class "A" Rayon stock.

Counsel have advised that there will be no income tax liability upon the holders of the Common stock of Industrial Fibre Corporation of America, provided they elect to take the shares of Industrial Rayon Class "A" stock instead of cash.

By the terms of the agreement, stockholders of Fibre Corporation have until February 1st, 1928, to elect to take Class "A" stock of Industrial Rayon Corporation. After that date, unless the date be extended, cash only at the rate above mentioned will be payable. You are therefore requested to surrender the certificates for Common stock of Industrial Fibre Corporation of America, to the Company, at the office of its Transfer Agent, the Corporate Trust Department of The Union Trust Company, Cleveland, Ohio. The certificates should be endorsed in blank

and election made as to which of the options the stockholder desires to exercise. A blank printed form is enclosed herewith for your convenience in delivering your stock.

Following is a statement of this company as of Feb. 15, 1929:

February 15, 1929.

To the Stockholders:

The management has devoted considerable time during the past three years to a program of elimination and reconstruction, and the re-alignment of those factors that make for economic production and distribution.

The certified audit of Messrs. Ernst & Ernst for 1928, made part of this report, marks the passing of an important milestone in the development and affairs of our company, and shows a net profit of \$1,653,601.83, after provision for Federal Income Tax.

Orders on hand from customers assure us a ready sale and distribution of our output for the first six months of 1929 at prevailing market prices.

Our Cleveland plant has been in continuous operation at full capacity throughout the year; but our contemplated small expansion at this plant was temporarily delayed due to more important work on hand. We are now proceeding to make the necessary additions, which will give us a total production of 5,000,000 pounds per annum at Cleveland four or five months hence.

We have been making good progress in the erection of our new plant at Covington, Virginia. We hope to have the first unit in operation on August first, and the entire plant in full operation by November first, this year.

With a contemplated production of ten to eleven million pounds per annum as the combined output of both plants by the end of the year 1929, and with the natural growth of the industry resulting from new uses, and with our major problems now behind us, we feel reasonably certain of our ability to achieve a fair measure of success in the further development of our company.

Respectfully submitted,

INDUSTRIAL RAYON CORPORATION,

HIRAM S. RIVITZ, *President*.

BALANCE SHEET

INDUSTRIAL RAYON CORPORATION—CLEVELAND

As of the close of business December 31, 1928

ASSETS

Cash on Hand and on Deposit.....	\$1,125,200.44	
Certificates of Deposit.....	30,000.00	
U. S. Government Securities—Market Value..	7,217,825.00	
Accrued Interest Receivable.....	72,297.31	\$ 8,445,322.75
Customers' Accounts and Acceptances Receivable, less Allowance for Doubtful Accounts, Discounts, etc.....		473,040.78
Creditors' Debit Balances.....		6,741.90
Merchandise Inventories at the lower of cost or market.....		422,553.55
Unpaid Balances on Subscriptions to Capital Stock, due in January, 1929.....		100,368.00
Water and Insurance Deposits.....		23,271.42
Miscellaneous Accounts Receivable, Advances, etc.		11,513.34
Plant and Equipment at Cleveland, based upon reproductive value as appraised by Coats & Burchard Company as of July 20, 1926, with subsequent additions at cost.....	\$4,174,628.41	
Less: Accrued Depreciation to July 20, 1926, as shown by appraisal report, plus subsequent allowances for depreciation.....	\$1,257,642.41	
Sound Value December 31, 1928, based upon appraisal		2,916,986.00
Covington, Va., Plant, Cost to date (A).....		807,953.62
Good Will, Patent Rights, etc. (Book Value).....		3,374,000.00
Deferred Charges, including unamortized portion of financing expenses.....		69,243.21
		\$16,650,994.57

LIABILITIES

Accounts Payable and Accrued Liabilities....	\$	553,675.73
Provision for 1928 Federal Income Tax.....		203,000.00
Provision for Redemption of minority shares of Common Stock of Industrial Fibre Corporation of America (1,506½ shares at \$7.50 each)		11,298.75
8% Debenture Gold Notes of Industrial Fibre Corporation of America—Due May 16, 1933, (10% of amount outstanding to be retired in 1929) Balance Outstanding.....		371,400.00
Reserve for General Contingencies.....		116,003.40

THE RAYON INDUSTRY

Capital Stock (No Par Value)

Authorized	200,000 shares
Issued	178,623 $\frac{3}{8}$ shares
Held for exchange for former issues of Class "A" and Class "B" stock.	4,085 $\frac{5}{8}$ shares
To be issued for subscrip- tions received.....	7,722 $\frac{3}{8}$ shares
	<u>190,431$\frac{1}{8}$ shares</u>

Stated Capital Value, \$60.00 per share..... 11,425,872.00

Surplus:

Capital—Paid in	\$1,511,998.92	
Profit and Loss.....	2,457,745.77	3,969,744.69
		<u>\$1,650,994.57</u>

(Note A) We are informed that the Company's new plant, including Equipment, under construction at Covington, Va., will cost approximately \$4,300,000.00.

(Note B) This Balance Sheet is subject to any necessary adjustment upon determination of the Company's final liability for Taxes, and to the comments in our "Certificate," included in and made a part of this report.

SUMMARY OF EARNINGS AND SURPLUS ACCOUNTS

INDUSTRIAL RAYON CORPORATION—CLEVELAND

For the year ended December 31, 1928

SUMMARY OF EARNINGS

Profit from operations before the following deductions		\$2,254,962.89
Deductions:		
Allowance for Depreciation.....	\$342,673.44	
Interest Charges.....	35,089.62	
Bond Discount	20,598.00	398,361.06
		<u></u>
PROFIT BEFORE FEDERAL INCOME TAX		\$1,856,601.83
Provision for Federal Income Tax.....		203,000.00
		<u></u>
NET PROFIT.....		<u>\$1,653,601.83</u>

CONSOLIDATED SURPLUS ACCOUNT

	Capital	Profit and Loss	Combined
BALANCE January 1, 1928, upon acquisition of Subsidiaries, In- dustrial Fibre Corporation of America and The Industrial Fibre Company, Inc.....	\$ 150,000.00	\$ 853,460.38	\$1,003,460.38

FINANCIAL

159

	<i>Capital</i>	<i>Profit and Loss</i>	<i>Combined</i>
ADDITIONS			
Net Profit from operations for the year ended December 31, 1928		1,653,601.83	1,653,601.83
Excess of subscription price over stated value of 95,215 ³ / ₄ shares of Capital Stock sold during year	1,349,802.00		1,349,802.00
Excess of purchase price of minority shares of Common Stock of Industrial Fibre Corporation of America acquired during 1928 over stated value of shares of Industrial Rayon Corporation issued therefor...	25,947.00		25,947.00
Reduction of minority interest in Common Stock of Industrial Fibre Corporation of America to \$7.50 a share.....		1,257.51	1,257.51
	<u>\$1,525,749.00</u>	<u>\$2,508,319.72</u>	<u>\$4,034,068.72</u>

DEDUCTIONS			
Discount on Debenture Notes retired in excess of annual pro rata requirement		\$ 47,685.12	\$ 47,685.12
Organization Expenses charged off	\$ 13,750.08		13,750.08
Additional Federal Income Taxes for prior years.....		2,888.83	2,888.83
TOTAL DEDUCTIONS...	<u>\$ 13,750.08</u>	<u>\$ 50,573.95</u>	<u>\$ 64,320.43</u>
BALANCE DECEMBER 31, 1928, AS SHOWN BY THIS REPORT	<u>\$1,511,998.92</u>	<u>\$2,457,745.77</u>	<u>\$3,969,744.69</u>

CONDENSED BALANCE SHEET

INDUSTRIAL RAYON CORPORATION—CLEVELAND

As of the close of business June 30, 1929

ASSETS

Cash on Hand and on Deposit.....	\$ 134,837.92	
Call Loans	5,600,000.00	
Certificates of Deposit.....	800,000.00	
Accrued Interest Receivable.....	32,521.45	\$ 6,567,359.37
Customers' Accounts, Notes and Trade Acceptances Receivable less Allowance for Doubtful Accounts, Discounts, etc.....		531,025.75
Creditors' Debit Balances.....		200.14

THE RAYON INDUSTRY

Merchandise Inventories at the lower of cost or market		613,657.71
Unpaid balances on Subscriptions to Capital Stock		1,946.00
Water and Insurance Deposits.....		27,832.61
Miscellaneous Accounts and Notes Receivable, Advances, etc., less Allowance for Doubtful, etc.		14,187.21
Plant and Equipment at Cleveland, based upon reproductive value as appraised by Coats & Burchard Company as of July 20, 1926, with subsequent addition at cost.....	\$4,383,207.62	
Less: Accrued Depreciation to July 20, 1926, as shown by appraisal report, plus subsequent allowances for depreciation...	1,405,878.15	2,977,329.47
Covington, Va., Plant, Cost to date (A).....		3,347,301.98
Good Will, Patent Rights, etc. (Book Value)		3,374,000.00
Deferred Charges		88,083.85
		<u>\$17,542,924.09</u>

LIABILITIES

Accounts Payable and Accrued Liabilities....	\$	800,124.34
Unpaid portion of 1928 Federal Income Tax		100,207.10
Provision for redemption of minority shares of Common Stock of Industrial Fibre Corporation of America (1,277½ shares at \$7.50 each)		9,581.25
8% Debenture Gold Notes of Industrial Fibre Corporation of America—Due May 16, 1933 (10% of amount outstanding to be retired May 16, 1930) Balance Outstanding		316,700.00
Provision for 1929 Federal Income Tax to June 30th		100,700.00
Reserves for General Contingencies.....		124,457.00
Capital Stock (No Par Value):		
Authorized	200,000 shares	
Issued	189,495¾ shares	
Held for Exchange for former issue of Class		
“A” Stock	907½ shares	
Subscribed	27¾ shares	
	<u>190,431½ shares</u>	
Stated Capital Value \$60.00 per share....		11,425,872.00
Surplus:		
Capital—Paid In.....	\$1,511,998.92	
Profit and Loss.....	3,153,283.48	4,665,282.40
		<u>\$17,542,924.09</u>

SUMMARY OF EARNINGS AND SURPLUS ACCOUNTS INDUSTRIAL RAYON CORPORATION—CLEVELAND

For the period of six months ending June 30, 1929

SUMMARY OF EARNINGS

Profit from operations for the period of six months ended June 30, 1929, before depreciation, interest and Federal Income Tax....			\$ 737,997.08	
Interest Earned	254,554.05	\$	992,551.14	
Less:				
Allowance for Depreciation.....	\$ 173,644.77			
Interest Charges	14,309.00			
Bond Discount	10,299.00		198,252.77	
PROFIT BEFORE FEDERAL INCOME TAX		\$	794,298.37	
Provision for Federal Income Tax.....			100,700.00	
NET PROFIT		\$	693,598.37	

SURPLUS ACCOUNTS

	<i>Capital</i>	<i>Profit and Loss</i>	<i>Combined</i>
BALANCE January 1, 1929.. ..	\$1,511,998.92	\$2,457,745.77	\$3,969,744.69
ADDITIONS			
Net Profit for the period of six months ended June 30, 1929...		693,598.37	693,598.37
Adjustment of 1928 Federal Income Tax Liability.....		1,939.34	1,939.34
BALANCE JUNE 30, 1929, AS SHOWN BY THIS REPORT.....	\$1,511,998.92	\$3,153,283.48	\$4,665,282.40

NOTE A: We are informed that the Company's new plant, including Equipment, under construction at Covington, Va., will cost approximately \$4,300,000.00.

NOTE B: This Balance Sheet is subject to the comments in our "Certificate," included in and made a part of this report.

Celanese Corporation of America was formerly the American Cellulose and Chemical Manufacturing Co. The capital structure and financial condition of this company are indicated by the following statement issued December 31, 1925:

ASSETS

Fixed Assets:

Cost of Properties:

Plant, Construction in Progress,
 Organization, Financing and De-
 velopment Expenses less Amount
 Reserved against amortization.. \$6,360,490.62

Real Estate:

Factory site—book value..... \$207,759.71
 Lots and houses at cost (subject
 to mortgages payable, as per
 Contra) 134,363.00

 342,122.71

Furniture and fixtures, at cost..... 13,632.75
 Patent Registration Fees, etc..... 27,295.72
 Patents and Goodwill..... ..

Total Fixed Assets:..... \$6,743,541.80

Current Assets:

Cash in Banks and on hand..... \$ 396,391.32
 U. S. Government Treasury Cer-
 tificates 1,103,577.35
 Accounts Receivable 262,674.10
 Accrued Interest Receivable..... 47,434.64
 Inventories at Cost..... 1,255,268.18

Total Current Assets:..... 3,065,345.59
 Deferred and Prepaid Charges..... 12,075.99
 Stocks and Bonds, at Cost..... 2,750.00

 \$9,823,713.38

LIABILITIES

*Capital Stock:**Authorized:*

150,000—7% Cumulative First Participating Pre-
 ferred Shares of \$100 each.
 100,000—7% Cumulative Second Preferred
 shares of \$100 each.

220,000—Common shares of no par value	
<i>Issued:</i>	
61,409—7% Cumulative First Participating Preferred Shares (dividends, Cumulative from January 1, 1924).....	\$7,042,400.00
95—7% Cumulative Second Preferred Shares (dividends cumulative from date of issue).....	8,000.00
206,050—Common shares of no par value.....	.....
Total Subscribed Capital:	
	\$7,050,400.00
First Mortgage 10-year 8% Convertible Sterling Bonds:	
Authorized £500,000. Issued £400,000 (at \$4.86 to the £)	1,944,000.00
Mortgages payable on lots and houses Purchased.	105,340.47
Current Liabilities:	
Wages Accrued	\$11,598.25
Accounts Payable	137,909.22
Tax Reserve	3,458.24
Total Current Liabilities:	152,965.71
Reserves	327,746.85
Surplus	243,260.35
	\$9,823,713.38

Since December 31, 1925, the capital structure has been changed in order to provide for expansion. Based on statements and figures given below from data issued on March 15, 1928 by F. S. Smithers & Co., member of New York Stock Exchange, one will note the extraordinary growth in the value of the securities in so short a time.

American Cellulose common stock was quoted in February, 1926 at \$72 to \$87 per share. These shares represented a capitalization in February, 1926, of a total of 200,000 common shares. In 1928 the capital common stock was increased to

1,000,000 shares and the quotation of these latter shares at the present writing, middle of the year 1928, is around \$75 per share. In other words the common capital stock was increased five times, with hardly any market price diminution. The original shares in two years increased from an average of \$75 per share to five times or \$375 per share.

The Celanese Corporation of America manufactures a product under the trade name "Celanese." The Corporation owns exclusively patents covering the production of cellulose acetate and artificial silk by the cellulose acetate process, non-inflammable celluloid, non-inflammable films, lacquers and varnishes. It also controls the Celluloid Corporation which has been granted an exclusive license under these patents for the manufacture of non-inflammable films and non-inflammable celluloid in the United States and South America.

The yarn factory of the Celanese Corporation of America commenced operations with a small capacity on January 1, 1925, which has been steadily increased. In April, 1927, funds were provided for doubling the capacity of its plants, which has now been nearly completed, and in June, 1927 funds were provided for further extensions which it is anticipated will be in operation early in 1929. The present issue of Prior Preferred Stock will provide for still further enlargements. Notwithstanding its steadily increasing manufacturing facilities, the Corporation has not been able to satisfy the demand for its products even at capacity operation.

Upon the completion of the present financing, the capitalization of the Corporation, which has no funded debt, will consist of

\$11,481,800 7% Cumulative Prior Preferred Stock,
\$14,817,900 Participating Preferred Stock,
1,000,000 Shares Common Stock.

Based on existing market quotations, the Participating Preferred Stock and the Common Stock represent an equity of about \$100,000,000 junior to the Prior Preferred Stock.

The growth of the manufacturing capacity of the Corporation has been reflected directly in its earning power. Earnings from operations have increased from \$305,360 in the year ended

December 31, 1925 to \$4,036,389 in the year ended December 31, 1927. The balance available for dividends in the calendar year 1927, after depreciation, reserves and other charges including \$127,260 interest and premium on redemption of bonds no longer outstanding, amounted to \$2,754,072 as compared with annual dividend requirements on the Prior Preferred Stock of \$803,726.

The balance sheet of the Corporation as of December 31, 1927 showed net tangible assets, including the proceeds from the present sale of Prior Preferred Stock, of \$33,300,000, equivalent to over \$290 a share on the Prior Preferred Stock. Included in these assets were 99,662 shares of Common Stock of the Celluloid Corporation, carried at a figure very substantially below the present market price. Valuing these shares on the basis of existing quotations would increase the net tangible assets to \$43,000,000, equivalent to over \$370 a share on the Prior Preferred Stock.

At its present price of approximately 108, the Prior Preferred Stock of the Celanese Corporation of America, which is callable only at 120, yields about 6.5%.

The Celanese Corporation of America in its report for the year ended December 31, 1928, revealed a net income of \$2,356,976, as against \$2,754,079 in the preceding year. Due to a large increase in preferred stock during the year, the balance available for the common amounted to 67 cents per share, as against \$1.72 in 1927.

Financial position of the company at the close of the year showed total current assets of \$20,510,631, as against current liabilities of only \$1,361,143. Of current assets, \$11,717,335 consisted of cash, marketable securities, and call loans, while \$469,214 of current liabilities consisted of a reserve for taxes and dividends payable.

American Bemberg Corporation: This company is of recent origin and since it published its report, it is reproduced here in full:

NEW YORK, N. Y., APRIL 27, 1928.

TO THE STOCKHOLDERS:

The Annual Report of American Bemberg Corporation for the year ended December 31, 1927, together with a balance sheet

and statement of profit and loss as certified by Messrs. Price, Waterhouse & Co., is submitted herewith.

The year 1927 was the first year during which the Company was in operation, the construction of the plant having been completed in November, 1926, and the machinery having been completely installed in October, 1927. The plant commenced operations immediately thereafter with a gradually increasing production until the full capacity of 7,000 pounds a day was reached in December, 1927. As a result of the plant's not having been operating to full capacity during the entire year, necessarily the ratio of expenses to sales has been an abnormally high one.

Bemberg, as your Company's product is known to the trade, although in successful use for many years abroad, is a novelty for American manufacturers. To suit the requirements of American users, adjustments in the method of production had to be made and a market for the finished fabrics had to be created.

In view of these initial difficulties the results as shown by our financial statement can be considered quite satisfactory. At the present time, we are operating at a profit.

The technical problems which every company faces at its inception have been successfully met and we are glad to be able to advise you that the goods which are now being produced by the Company are of a most satisfactory quality.

In July, 1927, your Company issued 140,000 shares of Class B Common Stock for the purpose of financing the construction of an additional unit which will increase the total capacity to 15,000 pounds a day. Very satisfactory progress has been made in the construction of the new unit and it is expected that it will be completed, equipped and in operation next August.

The demand for Bemberg yarn is steadily increasing, due to the fact that manufacturers in this country are realizing that it is the nearest approach to silk in feel, luster and appearance. Our yarn is sold to all branches of the textile trade and is already used largely in hosiery, knitted underwear, cotton weaving and silk weaving. Bemberg fabrics of all descriptions will soon be available to the consuming public.

A. MOTHWURF,
President.

AMERICAN BEMBERG CORPORATION

BALANCE SHEET

December 30, 1928

ASSETS

Capital Assets:

Real estate and buildings.....	\$2,537,180.08
Machinery and equipment.....	3,997,892.50

\$6,535,072.58

Less—Reserve for depreciation.....	650,611.16
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\$5,884,461.42

Development, experimental and organiza- tion expenses	214,439.01
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Patents, trade-marks, etc.....	99,484.27
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\$6,198,384.70

Investments, at Cost.....	30,285.52
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Current Assets:

Inventories (at or below cost):

Finished product	\$1,473,594.71
------------------------	----------------

Materials in process.....	25,631.57
---------------------------	-----------

Raw materials, supplies and samples	516,333.39
--	------------

\$2,015,559.67

Accounts receivable:

Trade debtors, less reserve \$	191,237.14
--------------------------------	------------

Current accounts of affili- ated companies	130,693.30
---	------------

Employees	26,671.47
-----------------	-----------

348,601.91

Notes receivable from officers, secured by real estate	24,008.86
---	-----------

Cash on hand, in banks and in transit.....	164,463.96
--	------------

2,552,634.40

Deferred Charges:

Insurance deposits, unexpired premiums and other prepayments	\$ 67,650.86
---	--------------

Other deferred items.....	13,906.18
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81,557.04

\$8,862,861.66

LIABILITIES

Capital Stock:

Preferred:

Authorized, issued and outstanding—
35,000 shares cumulative 7% of \$100
each \$3,500,000.00

Common:

Authorized, issued and outstanding—
140,000 shares of no par value..... }
Common—Class "B":
Authorized, issued and outstanding—
140,000 shares of no par value..... } 4,578,000.00

\$8,078,000.00

Current Liabilities:

Notes payable \$ 16,884.48

Accounts payable:

Trade creditors \$226,573.16

Accrued wages, salaries and
other accrued liabilities... 48,419.21

Employees 1,305.96

\$276,298.33

Dividend on preferred stock due January 1,
1929, appropriated out of accumulated
earnings 122,500.00

Federal income tax accrued..... 65,000.00

480,682.81

Surplus:

Deficit at January 1, 1928..... \$131,224.61

Profit for the year ending December 30,
1928 per statement attached..... 619,153.46

\$487,928.85

Dividends paid \$245,000.00

Less—Portion advanced un-
der guarantee as below.... 61,250.00

183,750.00

304,178.85

Note—Dividends upon cumulative 7% preferred stock have been guaranteed from July 1, 1925 to July 1, 1929 by Vereinigte Glanzstoff-Fabriken A.G. and J. P. Bemberg A.G. who have to date advanced \$673,750 for this purpose including \$61,250 on account of dividend paid July 1, 1928. The above named companies are entitled to repayment with interest at 5% of advances made under the guaranty agreement, out of profits after provision has been made for the then current dividends on the Preferred Stock.

\$8,862,861.66

FINANCIAL

169

FOR THE YEAR ENDING DECEMBER 30, 1928

Operating profit, before providing for depreciation, but after deducting selling, administrative and general expenses.....	\$1,044,252.97	
Depreciation	451,672.76	
Profit on operations		\$592,580.21
Interest earned	\$ 91,795.48	
Less—Interest paid	222.23	
		91,573.25
Provision for Federal income tax.....		\$684,153.46
		65,000.00
Net profit for the year, carried to balance sheet.....		\$619,153.46

We have examined the books and accounts of the American Bemberg Corporation for the year ending December 30, 1928 and find that the annexed balance sheet and statement of profit and loss are in accordance therewith.

Adequate provision has been made for depreciation of plant and equipment but no provisions have been made for the amortization or extinguishment of patents and development, experimental and organization expenses.

Subject to the foregoing, the accompanying balance sheet and statement of profit and loss, in our opinion, present fairly the financial position of the company at December 30, 1928 and the result of the operations for the year ending at that date.

PRICE, WATERHOUSE & CO.

56 Pine Street, New York.

April 25, 1929.

STATEMENT OF PROFIT AND LOSS FOR THE YEAR ENDING DECEMBER 31, 1927

Sales, less returns, allowances and discounts.....	\$1,513,210.31	
<i>Deduct:</i>		
Cost of goods sold (exclusive of repairs and maintenance and depreciation)....	\$1,050,738.31	
Repairs and maintenance.....	146,152.65	
		1,196,890.96
		\$ 316,319.35
Other income:		
Profit and discount on sale of consigned merchandise	\$ 10,261.47	
Commissions earned.....	8,661.73	
		18,923.20
		\$ 335,242.55
Selling, administrative and general expenses..		335,851.33
		\$ 608.78
Depreciation		108,938.40
Loss on operations.....		\$ 199,547.18

THE RAYON INDUSTRY

<i>Brought forward</i>	\$	199,547.18
Interest received	\$	83,699.48
<i>Less</i> —Interest paid		15,376.91
		<u>68,322.57</u>
Net loss for the year ending December 31, 1927 carried to balance sheet.....	\$	<u>131,224.61</u>

The directors and officers of the corporation are:

Directors

CARL BENRATH	KURT MEYER
DR. EDUARD BOOS	DR. A. MOTHWURF
DR. F. BLUTHGEN	RUDOLF ROSENHEIM
DR. J. C. HARTOGS	HENRY RUHLENDER
M. KORFF	ALFRED SCHOENLICHT
WILHELM LANGENBRUCH	JACOB STRAUSS
HERBERT LEHMAN	DR. W. SPRINGORUM

Officers

<i>President and Treasurer</i>	DR. A. MOTHWURF
<i>Vice-President-Secretary</i>	JACOB STRAUSS
<i>Vice-President</i>	MAX KORFF
<i>Assistant Secretary</i>	A. HUNZIKER
<i>Assistant Treasurer</i>	F. E. MUEHLEDER

As shown in this report a net loss of \$131,224.61 is indicated. This is hardly a barometer as to what this company will accomplish in its very near future. All Rayon plants for some time after commencing operations will show a loss, for this is the period when production is developed gradually. At the moment of this writing the American Bemberg Corporation is building and completing the second unit of 7000 pounds of Rayon, which is rapid enough progress in order to, more quickly than many expect, turn the above operating deficit into a substantial profit.

Following are excerpts from the Second Annual Report of this company as of December 30, 1928:

The above financial reports represent the large operating companies in the United States. The author endeavored to

obtain information on the smaller Rayon corporations direct from the officers or stockholders of these producing companies, but only the officers of the large corporations responded not only with a great degree of promptness but cooperated with the author in every request he has made for information.

The smaller companies now producing Rayon in the United States but which do not publish financial statements, are:

The **Skenandoa Rayon Corporation**, the plant of which is located at Utica, New York, using the Viscose process.

The **Belamose Corporation**, the plant of which is located at Rocky Hill, Connecticut, using the Viscose process.

The **Acme Artificial Silk Company** operating a plant under the Viscose process at Cleveland, Ohio.

The **Amoskeag Manufacturing Co.**, the well-known textile manufacturing company, with plants at Manchester, N. H., is operating a small unit for its own use, which it proposes to enlarge.

The **Delaware Rayon Corporation**, operating a small plant at New Castle, Delaware.

The following are the new companies which have been organized to produce Rayon in the United States:

The **American Glanzstoff Corporation**, affiliated with the Vereinigte Glanzstoff Fabriken of Elberfeld, Germany, has completed its first plant at Elizabethton, Tennessee, the capital for a proposed annual production of 4 to 5,000,000 pounds having been furnished by bankers in the United States. This plant started producing in 1929.

The **American Enka Corporation** has been organized by the Enka interests in Holland, with a capital stock of 500,000 common shares of no par value, of which 400,000 have been sold at \$60 per share. Only a small portion of this issued stock has been placed in the United States, most of which was purchased by Holland Enka, German and British interests. The

American Enka is controlled by the Enka Artificial Silk Company of Holland, organized in 1911 with a capital of 240,000 florins which now has a market value of 140,000,000 florins.

The proposed annual production capacity of the American Enka Corporation is 10,000,000 pounds.

The directors of the company are Frederic Allen, George A. Burr, O. L. Alexander, Franklin D'Ailier, P. R. Rockefeller, Philip Stockton, Jacques C. Hartogs, F. H. F. Van Clissingen and H. C. McEldowney.

The plant is located at Asheville, North Carolina.

The **A. M. Johnson Rayon Mills, Inc.**, has been built by Albert M. Johnson, President of the National Life Insurance Company of Chicago, at Burlington, North Carolina. No financial report has been issued. Capacity of the plant is to be 1,000,000 pounds of Viscose Rayon per year.

The **American Chatillon Corporation** is a company which was organized early in 1928. The shares were offered under date of May 21, 1928, by Blake Brothers & Co., De Saint Phalle & Co., and Maynard, Oakley & Lawrence, as agents of the corporation, sponsored technically and through patents by the La Soie de Chatillon, a corporation whose plants are operating in Italy.

The securities of this company were being offered to the public at the time of this writing and few details were known beyond the statements published, through the above mentioned fiscal agents, of Mr. D. M. Balsam, the chairman of the board of directors, which is given here practically in full.

May 21, 1928.

MESSRS. BLAKE BROTHERS & COMPANY
DE SAINT PHALLE & COMPANY
MAYNARD, OAKLEY & LAWRENCE

Gentlemen:

You have been appointed Agents to receive subscriptions for units of the preferred and common stock of the American Chatil-

lon Corporation, such units to consist of one share of the preferred stock (which will carry cumulative dividends from May 1, 1928) and one share of common stock at a price of \$111.00 per unit, to be paid in New York funds on or before June 15, 1928, upon allotment. In connection with your appointment as such Subscription Agents, I give you the following information in regard to the present status of the corporation.

The American Chatillon Corporation has been organized under the laws of Delaware with the following capitalization:

	<i>Authorized</i>	<i>To be presently Outstanding</i>
Preferred Stock ...	\$10,000,000	*\$5,000,000
Common Stock, No		
Par Value	†1,000,000 shares	540,000 shares

The Corporation has no bonded indebtedness, and has paid no cash for patents or processes, although about \$750,000 has been expended in their development. These patents are conservatively estimated to have a present worth of about \$5,000,000.

Upon completion of the present financing the pro forma balance sheet of the Corporation will be approximately as follows:

<i>ASSETS</i>	<i>LIABILITIES</i>
Cash	7% Preferred Stock Series A.....
Real Estate	Common Stock & Surplus
Furniture and Fixtures	Represented by 540,000
Plans and Patents, issued and pending....	Shs. no par value, issued
Organization Expenses	
Total Assets	Total Liabilities.....

* The Preferred Stock now being issued is Series A 7% Cumulative Convertible Preferred Stock, par value \$100. It is entitled to 7% cumulative annual dividends, payable quarterly February, May, August and November 1st, in preference to any dividends on the Common Stock, is redeemable at 110 dollars per share and is convertible into Common Stock in the ratio of one share of Common Stock for each share of Preferred Stock until Jan. 1, 1934. Remaining authorized Preferred Stock may be issued in series at such future times, in such future amounts, and with such provisions as the Board of Directors, in their discretion, may determine, provided, however, that no provisions of future series shall be more favorable than those of Series A.

† 50,000 shares of Common Stock are reserved for the conversion of Preferred Stock Series A.

The Corporation intends to erect and operate a plant at Rome, Georgia, for the manufacture of artificial silk by the acetate and viscose processes. The initial capacity of the plant will enable it to produce 6,000 pounds of acetate silk and 12,000 pounds of viscose silk per day during the first year of operation and this capacity may be increased later. Dr. Ugo Mancini, the well-known chemical engineer, is to supervise the erection of the plant and will act as general manager of the Corporation. He will be assisted by other officials of La Soie de Chatillon and the group will supervise the operation of the plant for seven years. The plant will be built by Lockwood Greene & Company.

The acetate of cellulose process to be used is entirely new and was developed by a group of French and Italian scientists of long experience and established reputation. The patents and processes are owned by the Ruth-Aldo Corporation and the American Chatillon Corporation has obtained exclusive rights to manufacture under these patents in the United States and Canada. The process has been in successful operation since September, 1926, in a plant owned by the Ruth-Aldo Corporation near Paris, France, and by La Soie de Chatillon, Milan, Italy, since June, 1927. It is expected that, because of the many valuable and unusual features of this process, it will be possible to manufacture artificial silk of greater elasticity, textile strength and resistance to heat at a lower cost than that manufactured by any other producer at the present time.

The viscose process to be used is the same that has been successfully used for many years by La Soie de Chatillon, Italy, and American Chatillon Corporation has the exclusive right to operate under the patents of La Soie de Chatillon in the United States and Canada.

The Chatillon Viscose unit started operation in July, 1929. It is expected that in the first full year of operation the Corporation will produce about 2,200,000 pounds of artificial silk by the acetate of cellulose process and about 4,500,000 pounds by the viscose process. Based on the most conservative estimates of production cost and market prices the Corporation should realize net profits, before preferred dividends and Federal Income Tax, of over \$3,000,000.

The officers of the American Chatillon Corporation are:

- D. M. BALSAM, *Chairman, Board of Directors.*
- M. BIROLI, *President.*
- U. MANCINI, *Vice-President.*
- T. SERVETTI, *Vice-President.*
- W. B. GELLARD, *Secretary.*
- M. E. TANHAM, *Treasurer and Assistant Secretary.*

The Board of Directors is composed of the following members:

- A. R. BALSAM, Secretary, McLellan Stores Company.
- D. M. BALSAM, Chairman, Board of Directors of American Chatillon Corporation and President, D. M. Balsam Company.
- DR. MARCO BIROLI, General Manager, La Soie de Chatillon.
- FURIO CICOGLA, First Vice-President, La Soie de Chatillon.
- SENATOR ETTORE CONTI, President, La Soie de Chatillon.
- H. S. DAVIS, Blake Bros. & Company.
- SIRO FUSI, President, Banca Commerciale Italiana Trust, New York.
- W. B. GELLARD, Secretary.
- A. E. GODDARD, Cullen & Dyckman, Counsel.
- C. C. LAWRENCE, Maynard, Oakley & Lawrence.
- L. LIEBENGUTH, de Saint Phalle & Company.
- W. W. McLELLAN, President, McLellan Stores Company.
- UGO MANCINI, Chief Engineer of La Soie de Chatillon and Vice-President of the American Chatillon Corporation.
- F. A. POWDRELL, Vice-President, W. T. Grant Company.
- T. SERVETTI, 2nd Vice-President, La Soie de Chatillon.
- M. E. TANHAM, Treasurer and Assistant Secretary.

Salaries now being paid to officers of the Company amount to the nominal sum of about \$16,700 a year, and are paid to one vice-president, to the secretary and to the treasurer. The other officers of the Company have voluntarily stated to the Board of Directors, that they will forego any salaries until the first fiscal year in which the books of the company show that earnings per share of Common Stock have been at least \$3.00

after preferred stock dividends, depreciation and other charges, but before Federal Taxes. After these earnings are obtained they will receive only nominal salaries until earnings available for the Common stock on the same basis are at least \$6.00 per share, at which time the Board of Directors will decide on further adjustment of salaries.

Very truly yours,

(Signed) D. M. BALSAM,

Chairman of the Board of Directors.

All the above new corporations are well and soundly financed, but every one except the Burlington plant, controlled by Albert M. Johnson, is practically controlled abroad, either technically or financially, or both. The United States, which is the most promising field for the Rayon industry, does supply the senior capital to most of these new plants with much of their junior voting securities lodging abroad. The tribute which will go to European interests from the United States on these junior securities when these plants are completed and operating will exceed fifty million dollars a year.

America is fully capable of financing and engineering its own Rayon plants and the plants which will be built within the next five years and it is hoped that a large, or at least a fair proportion will be controlled by American interests. The vision of Europeans for the possibilities of Rayon industry is so well founded that even the smallest investor abroad seeks a share in any Rayon company when the securities of any old or new company are offered to the public. Only recently the shares of the Cellulose Acetate Silk Company, Ltd., offered in England, were oversubscribed ten times.

While the American bankers realize Rayon securities, even of the most recent organized companies, will appreciate in value, the American public, excepting a small proportion, is not yet cognizant of this amazing situation in this revolutionary product of the textile industry, which only five years

hence will result in a production in excess of 250,000,000 pounds of Rayon per year in the United States alone. This amount is practically the world's present production. Even when this production has been reached our position as to demand will not have been changed since Rayon yarn, by then, will have found so many additional uses. When the world will be "Rayonized," which will happen not many years hence, it will prove to be a colorful age, for even the poorest will display, in his cotton textures, some Rayon colors—but when this happens Rayon yarns will be used in the ratio of fifty per cent of the output of cotton, wool and real silk, and all the textile mills, using Rayon yarn, will in reality be Rayon manufacturing mills.

This prophecy is based on past and current history of facts in the development of this phenomenal yarn, for even though a number of new companies are laying foundations for additional Rayon production, the older and well-established Rayon producing corporations are constantly enlarging their present mills, some of which are the following:

The Dupont Rayon Company is enlarging its works, adding an acetate plant at Meadville, Pa., and a Viscose plant at Richmond, Va., to its Buffalo, New York, and Old Hickory plant, Tennessee. Millions of dollars are being spent by the Dupont company in these new expansions.

The American Viscose Company is spending many millions on smaller expansions on the viscose process with a new unit on the acetate process.

The Industrial Rayon Corporations are adding a new viscose plant at Covington, Va., which it is stated will represent an investment of \$10,000,000.

The American Bemberg Corporation with its first plant at Elizabethton, Tennessee, which started operations early in 1927, has increased its capacity and is spending millions of dollars on its cupra-ammonium process.

The smaller companies, such as the Delaware Rayon Corporation, The Skenandoa Rayon Corporation, the Belamose Corporation and Amoskeag Manufacturing Company have also announced enlargements.

This expansion must not be thought to be spontaneous. It represents the careful study and analysis of the leading minds in the Rayon field. The confidence existing for this industry among those students who are reaping deserving millions is expressed by such happenings as represented by the rise in the market values of the securities of all Rayon making companies. Take for instance the shares of the American Cellulose Corporation, representing an investment of some \$15,000,000, have a market value of nearly one hundred million dollars. The Tubize Artificial Silk Company which represented an investment of approximately eight million dollars now has a market value of sixty million dollars.

The American Viscose Company's original investment is said to have been one million dollars, but no matter how much more it was, its present net profits of \$22,000,000, after large deductions for improvements and plant expansions, represents net earnings on a property which could be sold on the present market for at least \$500,000,000. No one, however, can buy any of this stock as most of it is owned by the British company, Courtauld's, Limited, which at its annual stockholders meeting of March, 1928, declared a dividend of approximately \$65,000,000.

The E. I. Dupont de Nemours & Co., which owns all the shares of the Dupont Rayon Company, can no doubt tell the same story. A holding company like this, realizing the potentialities of the shares of this industry, took them all, with not one share to the public. The public, if it wants any interest in this Rayon stock, must invest in the shares of the E. I. Dupont de Nemours & Company which owns

shares of other corporations. The same process is necessary to own any shares in the American Viscose Company, whereby ownership in the latter can only be had by buying shares in the British company, the Courtauld's, Limited. The same story can be written of the expansion and profits of many of the European companies. Japan, the home of raw silk, is beginning to draw its profits from Rayon making—which they use in the home market. Its poor populace will enjoy Rayon wearing apparel, while working and earning money in the raw silk industry, the output of which has not diminished, but rather increased greatly, as shown in another chapter, since Rayon yarn came in vogue in 1913.

From the study of the facts as evidenced by the financial side of these Rayon producing companies in the United States it is readily seen, particularly when these facts are considered in the light of the figures submitted under the chapter on the production of Rayon, one can readily determine that the future of Rayon securities, not only in the United States but Europe, Canada and Japan, is well founded and safe. Due to the necessity which everywhere compels the enlargement of the now operating plants, the shares of the present Rayon companies, if held for investment and not speculation, will be bound to appreciate in value just as they have safely done from the very inception of the industry except perhaps with few companies which have not been properly financed and managed.

Since the inauguration of a new Rayon plant demands considerable capital it devolves in most cases upon bankers to carry out a conservative fiscal program, and since the bankers know that safety of investment in the Rayon industry lies in the selection of good management, it is to the latter only that they will entrust the necessary capital. These safety guards imposed by the financial men, render the Rayon securities

safe with a very preponderant tendency to appreciate in value from year to year.

Market Quotations of Rayon Shares: In order to show how the Rayon securities have fared in the American market, a table is given herewith of the shares of such companies as are traded both on the New York Curb and Over-the-Counter Market. This table gives the high and low quotations for some of the shares for 1927, also from January 1, 1928 to August 31, 1928, and the high and low quotations for the month of August, 1928, which is the period in which the work on this volume was closed.

TABLE 32A. NEW YORK MARKET QUOTATIONS OF RAYON SHARES

Name of Corporation	Par Value	August, 1928		1928 to August 31		1927	
		High	Low	High	Low	High	Low
British Celanese.....	10s	\$17 $\frac{1}{2}$	\$12	\$33 $\frac{5}{8}$	\$12 $\frac{5}{8}$		
Amer. Celanese, com.....	No par	71	53 $\frac{1}{2}$	103	53 $\frac{1}{2}$	\$315*	\$44
Amer. Celanese, 1st pref....	\$100	135 $\frac{1}{4}$	121 $\frac{1}{4}$	185 $\frac{1}{2}$	121 $\frac{1}{4}$		
Amer. Celanese, new pref....	100	104	100 $\frac{1}{2}$	112	100 $\frac{1}{2}$		
Courtaulds, ord.....	£1	21 $\frac{7}{8}$	21 $\frac{1}{4}$	24 $\frac{7}{8}$	21 $\frac{1}{4}$	38 $\frac{1}{4}$	24 $\frac{7}{8}$
Industrial Rayon.....	No par	85 $\frac{1}{4}$	81 $\frac{1}{8}$	97	78 $\frac{3}{4}$		
Tubize "B" shares.....	No par	540	475	630	450	499	145
Canadian Celanese, com....	No par	47 $\frac{1}{4}$	38 $\frac{1}{2}$	78 $\frac{1}{2}$	38 $\frac{1}{2}$	86	52 $\frac{3}{4}$
Canadian Celanese, pref....	\$100	82 $\frac{1}{2}$	80	103 $\frac{1}{2}$	80	103	88
Amer. Chatillon, com.....	No par	.....	.....	38	11		
Amer. Chatillon Units, 1st pref. and 1st com.....	Pref. \$100	.....	.....	120	111		
Amer. Bemberg Corp., pref..	No par	135	120	168	70	90	65
Amer. Bemberg Corp., com..	No par	135	120	168	70	90	65
Amer. Glanzstoff Corp., pref.	\$100						
Amer. Glanzstoff Corp., com.	No par	105	110	135	70	80	60

* Regular and special dividend.

CHAPTER VI

CHARACTERISTICS OF RAYON AND THE COMMON TEXTILE FIBRES OF COMMERCE

THE common textile fibres in the order of their world consumption are cotton, wool, linen, Rayon, silk and ramie. The

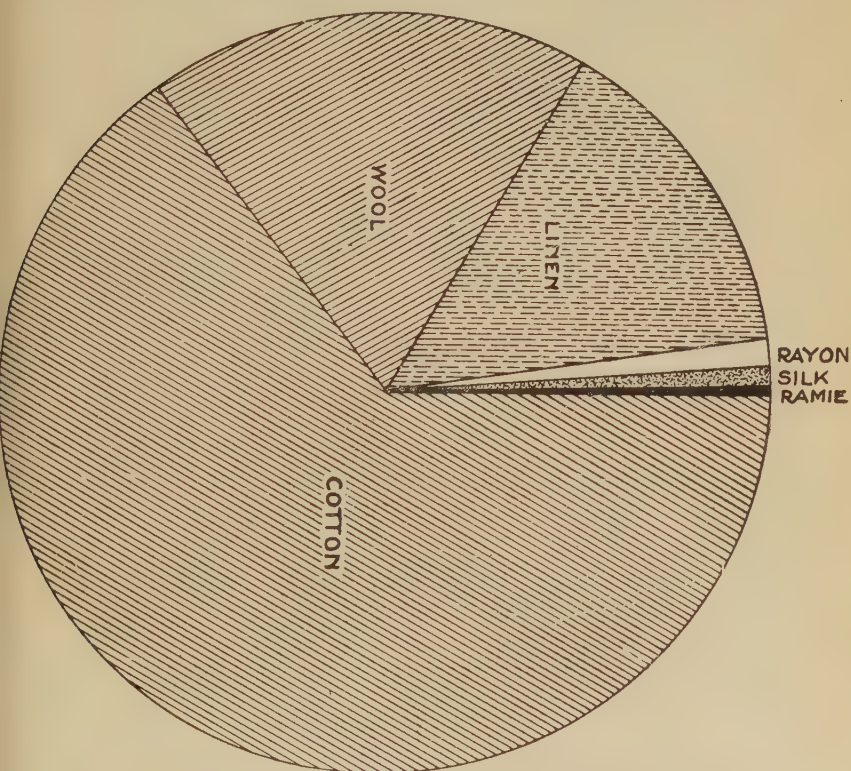


FIG. 7. World Production Ratio of the Common Textile Fibres.

comparative world production of these fibres in 1926 was approximately as follows:

	<i>Pounds</i>
Cotton	14,017,000,000
Wool	3,000,000,000
Linen	2,000,000,000
Rayon	219,000,000
Silk	92,000,000
Ramie	29,000,000
	19,357,000,000

This production ratio is shown graphically (see Fig. 7).

Since 1914 the production trend of cotton, wool, linen, and ramie has been downward while that of Rayon and silk has been upward, with Rayon passing silk in its upward swing in 1921 (see Chart 5).

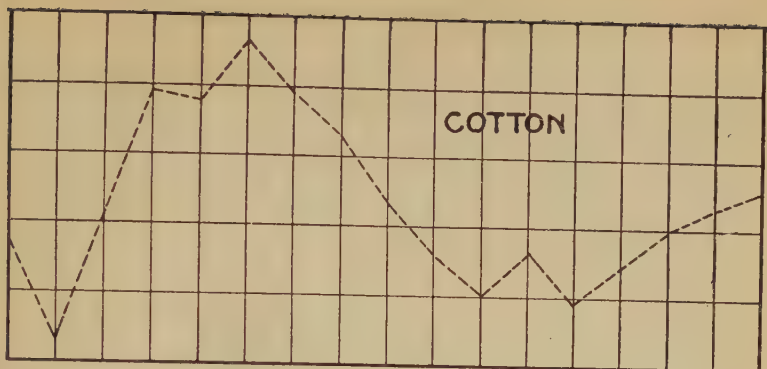
RAYON: CHARACTERISTICS OR PROPERTIES OF RAYON

The principal properties of Rayon to be considered are the physical, chemical, mechanical and colloidal.

PHYSICAL PROPERTIES

Under physical properties come the color, luster and thermal conductivity. However, the most important physical properties of Rayon are the optical, that is, those concerned with color and luster rather than thermal conductivity.

Color—Different results are obtained in the color of Rayons obtained from wood-pulp as against those produced from cotton. The color of Rayon yarn obtained from wood-pulp is pale cream while that obtained from cotton is bluish-white. In order to obtain pure white Rayon yarn from wood-pulp, it is often necessary to "blue-bleach" the silk with certain dyes



COMPARATIVE WORLD PRODUCTION OF TEXTILES

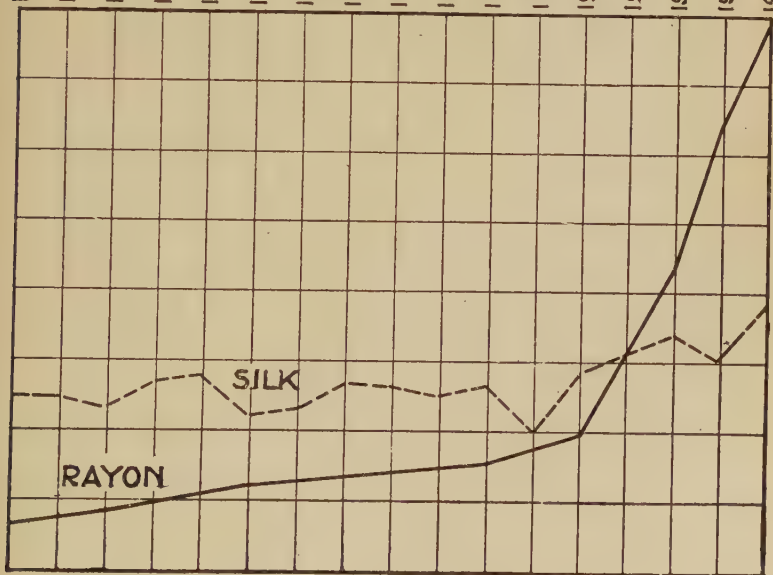
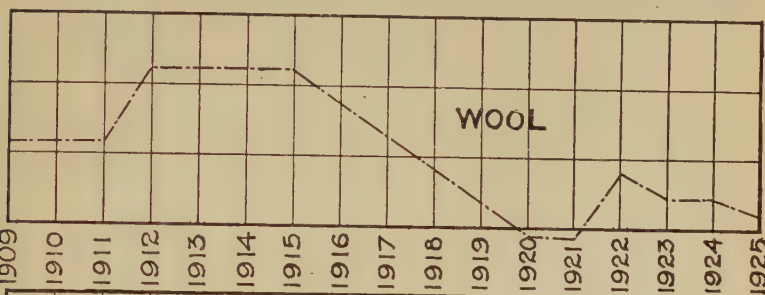


CHART 5: Comparative World Production of Textiles, Showing Rayon Passing Silk in 1921.

in order to neutralize the cream color of Rayon. This applies mostly to the Viscose process. The Rayon yarn made under the Viscose process is sometimes bleached and other times left unbleached. In its unbleached state it is straw colored. It is left unbleached so that it may be used for dyeing in darker shades.

Luster—The luster of Rayon yarn surpasses silk in glossiness. This is due to the fact that Rayon fibres are flatter than silk and therefore reflect more light. To a certain extent the luster is determined during the spinning process and depends on the initial stretching of the thread while in a wet condition. This applies particularly in connection with the Viscose and Cupra-ammonium processes which use the wet method of spinning. The luster also depends to some extent on the impurities and the size of the individual filaments and on the quality of luster of the inner and outer structure of the filaments. The luster of Rayon can be reduced by giving the yarns more twist. All producers of Rayon, however, aim to maintain a uniform luster in their yarn.

There is a distinct difference in the luster of the various kinds of Rayon yarn. Thus, Nitro-cellulose or Chardonnet Rayon has a tinny lustre; that is, it has a glistening metallic luster. Cupra-ammonium Rayon yarn is almost glossy in appearance. Viscose Rayon yarn may be described as silvery. Cellulose Acetate Rayon yarn has a luster of the nitro-cellulose variety, silvery or of a subdued glistening.

For manufacturing of Rayon into finished merchandise it was necessary to reduce the luster of Rayon, which was done by variations in its production. Thus in the case of the Viscose Rayon yarn, the luster could be eliminated by leaving sulphur in the filament. The luster can also be changed to some extent by treating the yarn with certain strengths of alkalis, acids and colloids.

To remove the luster from cellulose acetate Rayon yarn,

steam or boiling water is applied with solution of salts and sugars. The luster can be restored to the cellulose acetate after treatment with acetic acid, and other organic compounds.

Since the luster of any Rayon, therefore, can be adjusted to specified requirements it can be seen that the appearance of Rayon yarn is beginning to approach that of real silk.

A. Herzog has conducted studies to determine the optical characteristics of the different Rayons. These studies cover examinations by the X-ray spectroscope, which have shown

TABLE 33.—REFRACTIVE INDEX OF RAYON YARNS COMPARED TO OTHER FIBRES

Fibre	μ_D	μ_D	Mean Refractive Index
	Axis of Thread at Right Angles to the Plane of Polarization	Axis of Thread Parallel to the Plane of Polarization	
Silk.....	1.595	1.538	1.567
Flax.....	1.595	1.528	1.562
Spun silk.....	1.581	1.542	1.562
Cotton.....	1.580	1.533	1.557
Wool.....			1.551
Nitro-cellulose silk.....	1.548	1.518	1.532
Cupra-ammonium silk....	1.548	1.527	1.538
Viscose silk.....	1.548	1.524	1.536
Cellulose-acetate silk.....	1.474	1.479	1.477

that all these yarns except the cellulose acetate Rayon display a crystalline structure or symmetrical form like the mercerized cellulose. Such studies by ultra-microscope also show that the Rayons, while having a definite difference among themselves, have a net-like structure. Herzog had also determined the refractive index of Rayon yarn as compared to other fibres which is given in Table 33.

Such studies as conducted by Herzog microscopically are

proving of great help, as they will expose variations and faults in the production of Rayon yarn.

Of interest also is a recent device known as the glarimeter, an optical instrument invented by Georz, which indicates the luster of fabrics by comparing the result quantitatively to an arbitrary scale.

MECHANICAL CHARACTERISTICS OR PROPERTIES OF RAYON

The mechanical characteristics of Rayon yarn take into consideration tenacity and elasticity, feel and softness, and covering power. As a general consideration, however, we will first consider specific gravity.

Specific Gravity—Rayon is heavier than real silk, having a specific gravity of 1.50 as compared to 1.25 for silk. Here-with follows comparative figures on specific gravities of the different fibres:

	<i>Specific Gravity</i>
Rayon	1.50
Silk (raw)	1.30-1.37
Silk (boiled off)	1.25
Wool	1.34
Flax	1.50
Ramie	1.50

Studies on the specific gravity of Rayon fibers, were conducted by A. Herzog, of the Courtauld Laboratories, and Foltzer by different methods. All the determinations on the specific gravity by the different investigators are practically alike, the differences being slightly in excess of 1.50 but none below 1.50, except the cellulose acetate, which, according to Herzog's examinations in 1922, gave the specific gravity as 1.26.

Tenacity and Elasticity—One of the greatest efforts which the Rayon producer has been making for years is towards increasing the tenacity and elasticity of Rayon yarn, as this was

one of the weaknesses, or the inferiority, of this textile fiber as against real silk, especially when wet.

Various types of machines have been developed for testing the tenacity and elasticity of these yarns. The methods of testing in order to obtain these determinations in figures have been fully discussed and the devices shown in the Chapter on Testing.

The United States Bureau of Standards has published the following figures showing the dry and wet tenacity, and their breaking strength, of the several kinds and sizes of Rayon yarn. (See Table 34.)

TABLE 34.—BREAKING STRENGTH OF RAYON YARNS AND SILK

Fibre	Size of Denier	Tenacity or Breaking Strength, Grams		Per Cent of Loss
		Dry	Wet	
Cupra-ammonium.....	150.0	173.9	40.7	76.5
Nitro-cellulose.....	150.0	218.0	86.6	60.2
Viscose.....	150.0	190.0	74.6	60.7
Acetate.....	150.0	157.1	88.0	43.9
Silk (12 thread).....	138.8	515.1	416.3	19.1
Viscose.....	300.0	365.5	131.8	63.0
Acetate.....	300.0	335.5	186.5	44.4

To test for the wet elongation, it is required to wet the whole length of the thread, whereas to determine the wet tenacity it is sufficient to immerse only about four inches in the middle of the thread. However, to obtain the wet tenacity of viscose, cupra-ammonium and nitro-cellulose Rayons, it is necessary to immerse in water for 30 seconds, and in the case of cellulose acetate for 15 minutes. There is a great reduction in the tenacity of Rayons in wetting. The wet tenacities seldom are 50 per cent of the dry for the viscose, cupra-

ammonium and nitro-cellulose. The cellulose-acetate Rayon, however, has a greater resistance to water. This will be seen from the above table where the fibres are compared for dry and wet tenacity.

There is also difference in the elasticity or elongation of the various Rayon fibres. Cupra-ammonium Rayon has the lowest percentage of elasticity, which is due to the stretching in spinning. According to Dreaper, in the cupra-ammonium process, the Rayon filament has a skin, and the strength of this skin, and the relation of the surface of same to the cross-sectional area determines the strength and elasticity. When the proportion of skin is the greatest, the elasticity is the least.

Average results for the elasticity are as follows:

<i>Fibre</i>	<i>Per Cent of Elasticity or Elongation</i>
Silk	21.0
Viscose Rayon	20.0
Nitro Rayon	15.5
Cupra Rayon	12.5

Both the breaking strength and elasticity have been, and can be, improved by better processes for the production of Rayon, finer and more uniform deniers, and more uniform twisting. As the fineness of the individual fibres is increased, the feel and luster become softer. Some chemical methods have been and are being used to increase strength by the application of dilute acids, etc. Some are fairly good in their results. The cross-section of Viscose Rayon as illustrated in Figure 8 shows sharp corrugations which interlock and help to give the threads strength. Nitro-cellulose, or Cardonnet Rayon, is more oval and only slightly corrugated. The cross-sections of Acetate and Cupra-Rayon show practically no corrugations at all. See Figs. 8, 9, 10, 11, 12, and 13.

NOTE: Figs. 8, 9, 10, 11, 12, 13, 15, 16, 25, 26, 27, 28, 29, 30, 31 and 32, appearing in this chapter, were reprinted by permission from "Textile Fibres," by J. Merritt Matthews, published by John Wiley & Sons, Inc.



FIG. 8. Cross-section of Viscose Rayon.

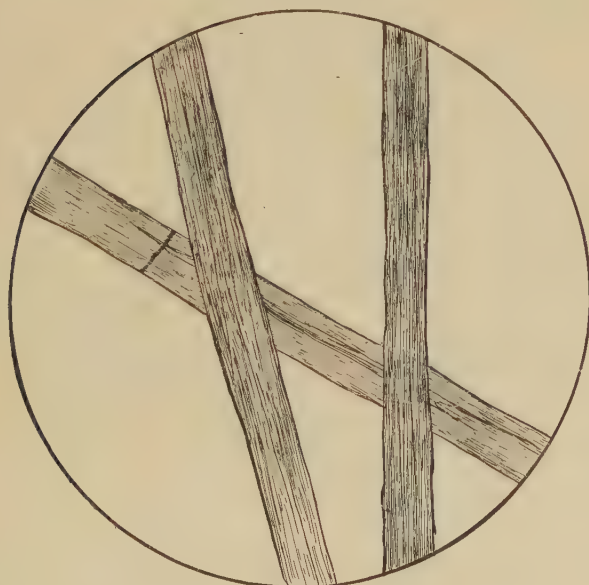


FIG. 9. Viscose Rayon.

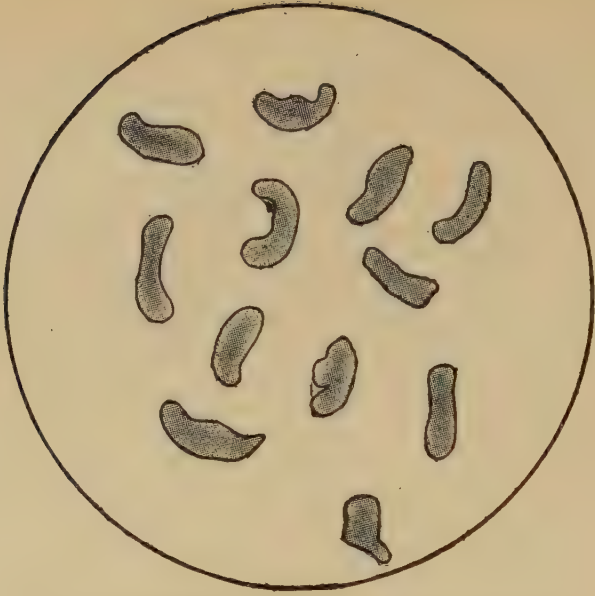


FIG. 10. Cross-section of Nitro or Chardonnet Rayon.

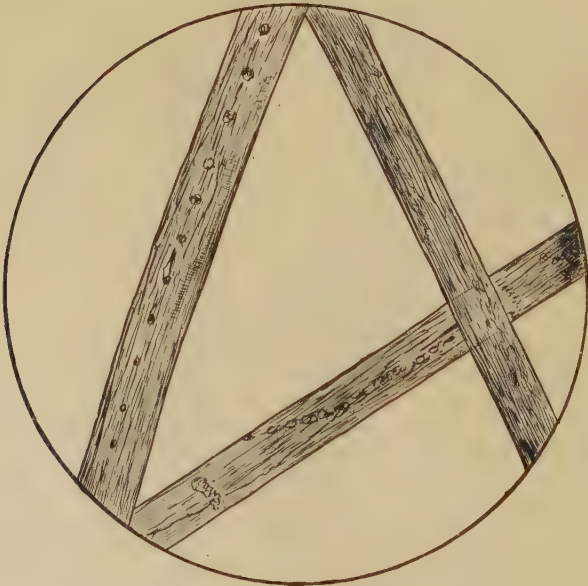


FIG. 11. Nitrocellulose or Chardonnet Rayon.



FIG. 12. Cross-section Cupra-ammonium Rayon.

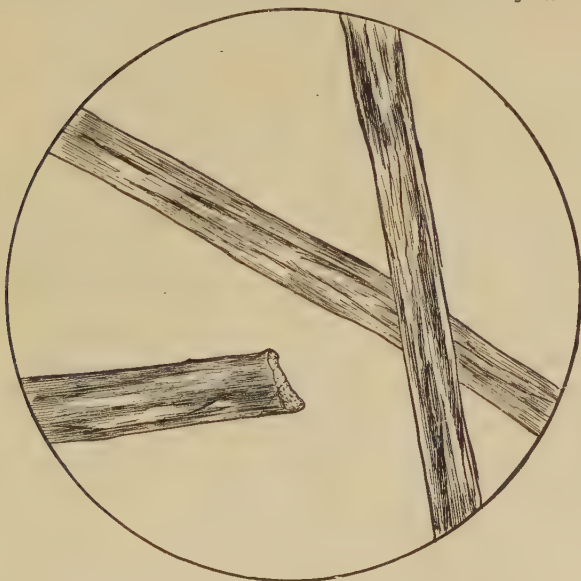


FIG. 13. Cupra-ammonium, Glanzstoff Rayon.

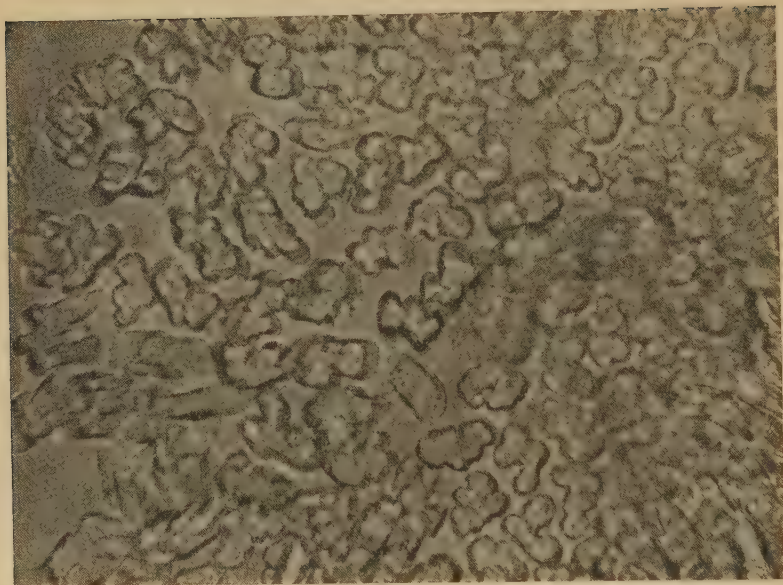


FIG. 14. Cross Section of Acetate Rayon Yarn (Celanese). (Courtesy Associated Knit Underwear Manufacturers of America.)

Although the wet strength of all kinds of Rayon is much less than the dry, this defect is somewhat overcome by increasing the twists per inch. To overcome this inherent imperfection of Rayon much research has been conducted in an effort to find a treatment of the fibres which will effectively waterproof them. This is indeed an important problem, and its successful solution would have a far-reaching effect on the industry. Waterproofing by treatment with formaldehyde and lactic acid is used to some extent, but this method has the drawback of making the fibres harsh and hard and interfering with some of the dyeing operations. Treatment of Viscose Rayon with aluminum acetate during de-sulphurization is also said to have a waterproofing effect.

In some respects Rayon's tendency to absorb water is an advantage. Its use in underwear combined with cotton has

been very successful as it absorbs perspiration and leaves the skin cool and dry. Rayon is not discolored or rotted by perspiration, nor is it affected by bacterial action of any kind, therefore Rayon fabrics do not mildew.

For winding and weaving Rayon yarns, lack of sufficient elasticity is one of the important disadvantages. When tension is applied to the Rayon thread the elongation up to half the breaking strength is small, but when further tension is applied the increase in elongation is more rapid. Thus in winding or weaving, Rayon thread of 150 denier may be reduced to 130 if too great a tension is applied to it.

CHEMICAL AND COLLOIDAL CHARACTERISTICS

The action of water, salt, soap, bleach solutions, dyes, alkalis and acids upon Rayon has been studied and problems of practical importance have thus been solved. While such reagents have been used for many years in connection with all the other natural textile yarns the application of these reagents did not meet with success at the beginning and not until Rayon yarns were properly understood. Rayon yarns behave when treated with such reagents as follows:

Water—The average moisture content of viscose, cupra-ammonium and nitro-cellulose artificial silks ranges between 11 per cent and 15 per cent, depending on the humidity. Cellulose-acetate yarn has a lower moisture content, usually from 3 to 6.5 per cent, and is less affected by changes of atmospheric humidity.

The U. S. A. Customs specifies for a regain in moisture of the dried Rayons at 70° F. and 65° relative humidity the following figures:

Viscose, Nitro-cellulose	}	14 per cent of the dry weight
Cupra-ammonium		
Cellulose acetate		6.5 per cent of the dry weight

Salt Solutions—Various experiments to determine the effect of chemicals on Rayon yarns have recently been made. Rayon yarn has been treated with strong salt solutions and then treated with roughening agents such as talc. In this manner the adhesive properties of the thread are increased, thus increasing the wearing value in combination with other fibres. This is due to the absorptive powers of Rayon yarns and makes it possible to render this synthetic textile valuable for the manufacture of incandescent mantles which are harder and stronger than those manufactured from flax or ramie.

Alkaline Solutions—Boiling alkaline solutions, souring Rayon yarns soften the yarns, making them tender and liable to damage. It therefore requires care when it comes to the treatment of Rayon yarns with such solutions. It has been found, however, that strong caustic alkali has no effect on cellulose-acetate Rayon provided the treatment is carried out for short periods at moderate temperatures. This makes it possible to treat mixtures of cotton and cellulose-acetate Rayon with caustic alkali of mercerizing strength, in order to mercerize the cotton present.

Acids—After alkaline or bleach treatments have been given to the Rayon yarn the acid solutions are used as souring baths. These acid solutions have no detrimental effect on the Rayon yarn if the acid is completely washed out of the yarn before drying. If acids are left in the yarn it becomes weaker. If strong acids are used they affect the mercerizing action. When certain organic acids are employed the scrooping effect on Rayon yarn is obtained.

Scrooping—The scrooping of silk, which is responsible for the characteristic “rustle,” may be imparted to Rayon by treatment with dilute solutions of acetic, tartaric or formic acids. The scrooping of real silk does not seem to be an inherent property, but is also produced by treatment with dilute acids. Even cotton and wool can obtain this quality of scroop

through mercerization. The scroop of Rayons is obtained after dyeing. Rayon yarn is first treated with a warm soap bath and then hydro-extracting it in a cold acid bath made up of the acids mentioned above, after which the Rayon yarn is dried.

COLLOIDAL SOLUTIONS

Under colloidal solutions come (a) Sizing; and (b) Soaping.

Sizing—The sizing of Rayon yarn is done to increase the tenacity of the thread and resistance to friction in weaving. For sizing Rayon yarn gelatine containing a small amount of Turkan oil is largely used. Gum arabic, gum tragacanth and glycerol are also used. There are numerous other mixtures which are being found from time to time to accomplish this operation of sizing, such as waxes, oils, aqueous emulsions and fatty acids. In the United States more than in Europe the application of oil has been adopted in order to prevent the rubbing of the threads rendering them more pliable and keeping out the moisture. This application of oils in sizing has been discussed again in Chapter XVII, on Processing and Manufacture of Rayon Yarn.

Soaping—In order to render the Rayon yarn soft, it is soaped prior to bleaching or during or after dyeing. Soaping therefore is applied as a finishing treatment, that is, immediately after the Rayon yarn is finished and ready for bleaching. It is applied after dyeing to increase the fastness of dyeing.

For the cellulose-acetate silk boiling soap solutions are used, as otherwise the luster would be lost.

In soaping Rayon under the viscose, cupra-ammonium and nitro-cellulose processes either olive oil soap or the Turkey-red oil preparations are used. Soaping is carried out at

boiling point for approximately two hours with solutions, the strength of which are from $\frac{1}{2}$ to 1 per cent.

Bleach Solutions—Bleaching solutions are applied to Rayon in order to render it pure white. All bleaching must be done under carefully controlled conditions so that the action of bleaching solutions which tend to oxidize the coloring matter is reduced to a minimum. These oxidizing reagents act on the cellulose tending to produce oxycellulose which is a weaker product than the original cellulose. Tests made after bleaching of Rayon yarn prove that there is a reduction in the strength of the yarn when it is overbleached.

The dyeing of Rayon yarn is discussed in all its phases for the different processes in Chapter XVII, entitled "Processing and Manufacture of Rayon Yarn."

Having discussed the properties of Rayon the reader is referred to a classification of silks, according to A. Herzog as given in the Chart 6. Even though classified under silk, Rayon (in the chart called Artificial Silk) stands as a vegetable textile distinct from that of natural or animal silk.

Since Rayon is properly being recognized as a distinct and separate member of the textile family, and since its place is not to displace or replace any of the other textiles but rather to supplement them it is considered opportune to devote some space to a discussion of these other textiles such as cotton, wool, linen, ramie and silk.

Cotton—King cotton, the universal fibre, is of vegetable origin and comes from the pod of the genus *gossypium*. The use of cotton as a textile fibre dates back to prehistoric times. The earliest source of cotton was India, which country held the lead in cotton production up to the sixteenth century of the Christian era. From India its production and use have spread over the world. The principal producing countries in the order of their volume are today the United States, British India, Egypt, Russia, China, Brazil and Turkey.

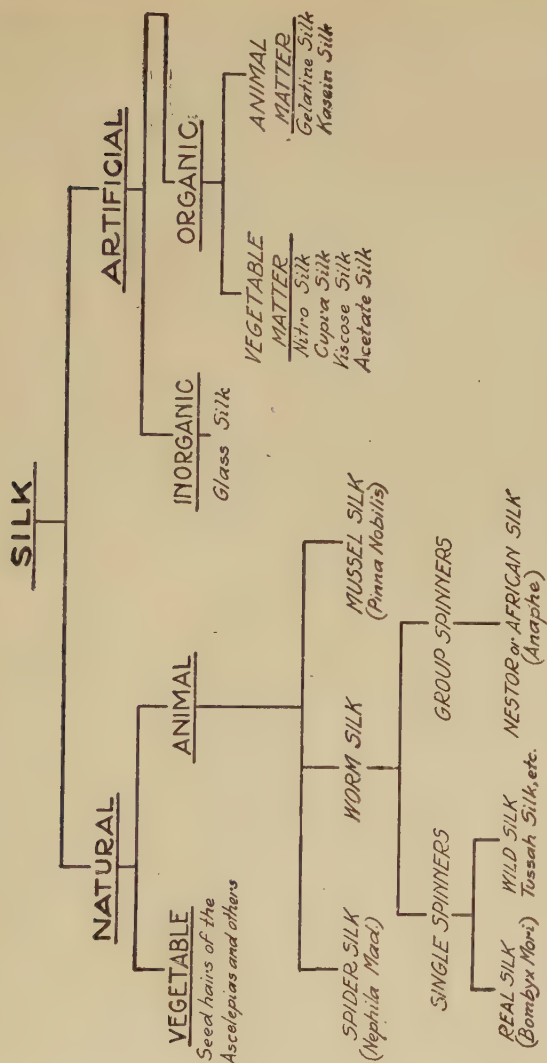


CHART 6. Chart Showing the Classification of Silks According to A. Herzog.

Hannan gives the following varieties and qualities of cotton, which are of commercial importance:

Sea Island—Edisto, Florida, Fiji, Tahiti.

Egyptian—Brown, Gallini, Menouffieh, Mitafifi, White.

Peruvian—Rough, Smooth, Red.

Brazilian—Pernambuco, Maranhão, Ceará, Paraíba, Rio Grande, Macaé, Santos, Bahia.

American—Orleans, Texas, Allamogosa, Mobile, Norfolk, St. Louis, Roanoke, Bowdoin, Benders, Memphis, Peelers, Uplands, Alabama, Linters, Tennessee.

Greek—Smyrna.

African—Lagos.

West Indian—Carthagen, La Guayana.

China—China.

Australian—Queensland.

East Indian—Poompuh.

East Indian—Hingunghat, Comptah, Broach, Dharwar, Assam, Bengals, Bilatu, Dhollerah, Surat, Scinde, Tinnevely, Bhowmuggar, Cocanada, Bourbon, Khandeish, Madras of Western, Rangoon, Kurrachee.

Italian—Calabria.

Turkey—Levant.

Trotman describes the principal commercial varieties of cotton as follows:

SEA ISLAND COTTON: This is the highest type and most valuable of commercial cotton. It is grown on the Gulf coast of Florida, in the Barbados, and other islands where soil and conditions of climate are specially adapted to the requirements of the cotton plant. The average length of the fibre is nearly two inches, and its diameter is less than that of any other cotton, viz.: 1/1500 of an inch. Owing to its fineness, it can be used for spinning yarns of the highest counts, 200's to 400's. Sea Island cotton is also characterized by its evenness, and its large proportion of fully ripened fibres accompanied by highly developed twist. But its most striking property, in comparison with other cottons, is its

softness and highly developed lustre. Its color varies from white to cream. There are several kinds of Sea Island cotton, such as Florida, Queensland, Fiji.

EGYPTIAN COTTON: There are two kinds of Egyptian cotton, viz., brown and white. The brown variety is finer than the white. It is, like Sea Island, very regularly developed, with but few immature or dead fibres. Its length of staple and diameter approach those of Sea Island cotton, averaging 1.5 to 1.75 inches, and $1/1500$ inch respectively. It can be spun up to 200's. The brown color, which is somewhat variable in depth, makes it difficult to mix this and other cottons in the unbleached condition. White Egyptian cotton is not so fine as the brown, its staple being not much more than 1 inch in length. It cannot be spun alone to a higher count than 70. White cottons are occasionally artificially stained to resemble brown Egyptian.

SOUTH AMERICAN COTTON has a medium length of staple, from 1 inch in the lower to 1.5 inch in the higher grades. It is strong, but rather irregular and harsh. This is due, probably, to rapid drying up. It is used alone for counts up to 70's or mixed with other cottons of shorter staple. South American cotton has a mean diameter of $1/1300$ inch.

AMERICAN COTTON is grown in the United States. There is a large number of varieties, produced by selective cultivation, some of which, such as Allanseed, Peeler and Bender, have an average length of 1 to 1.25 inch, and are used for spinning counts up to 70's or 80's. The lower grades, such as St. Louis, average 0.9 inch in length, and are not used alone for counts much above 32's. American cotton is rather coarser than that of South American, its diameter averaging $1/1300$ inch. It is characterized by its good color and cleanliness, and in good seasons by the regularity of its staple.

INDIAN COTTON has a comparatively short staple, from 0.6 to 0.8 inch. It is only suitable, therefore, for the spinning

of low counts. It is also somewhat harsh. Tinnevelly cotton is the most valuable variety. Indian cottons are sometimes called Surats, after a particular variety.

CHINA COTTON: This is a good example of a low-grade cotton. The fibres are short, 0.5 to 0.7 inch, harsh, and coarse. The twist is not highly developed. It has little use except for mixing.

TABLE 35.—A SUMMARY OF THE COMPARATIVE PROPERTIES OF THESE VARIETIES

Origin of Cotton	Length of Fibre, in Inches	Diameter in Inches	Spinning Power
Sea Island.....	2 and over	1/1500	400's
Egyptian.....	1½ to 1¾	1/1500	200's
South American.....	1 to 1½	1/1300	70's
American.....	0.9 to 1¼	1/1300	70's
Indian.....	0.6 to 0.8	1/1200	low
Chinese.....	0.5 to 0.7	1/1200	low

Chemically pure cotton fibre contains carbon, hydrogen and oxygen in the form of cellulose, a carbohydrate. There are traces of an outer waxy or oily layer and of an inner pigment, which are removed in the boiling out and bleaching processes. There is also present albuminous matter and about 1 per cent of mineral matter, which constitutes the ash left on ignition. Cotton is less hygroscopic than either wool or silk and under atmospheric conditions contains from 6 to 9 per cent of hygroscopic moisture. The hygroscopic quality of cotton has much to do with its proper condition during spinning and finishing. It is also important in valuing the staple as a raw material, and standard conditions of reference are necessary for this purpose. The strength and elasticity of cotton are markedly influenced by the amount of hygroscopic moisture present.

Thompson gives the following figures for the effect of moisture on cotton yarn:

<i>Moisture in yarn, per cent</i>	<i>Breaking Strain</i>
2.89 (dry)	39.9
8.93 (usual)	64.0
17.36 (moist)	69.2

TABLE 36. EFFECT OF MOISTURE ON THE STRENGTH AND ELASTICITY OF VARIOUS COTTON YARNS (OESTER).

Material	Strength, Ounces		Elasticity, Per Cent	
	Dry	Moist	Dry	Moist
20's cotton yarn, gray.....	25.5	28.1	3.1	3.9
20's cotton yarn, bleached...	24.7	24.8	3.7	4.2
40's cotton yarn, gray (American).....	9.1	10.6	2.4	2.9
40's cotton yarn, gray (Egyptian).....	11.2	11.3	2.5	3.1
40/2 cotton yarn, gray (hard twist).....	24.2	27.3	2.4	3.6
40/2 cotton yarn, bleached (hard twist).....	25.6	23.3	3.9	3.1

MICROSCOPY

Under the microscope cotton appears as a flat ribbon-like band more or less twisted. The twists may be right- or left-handed and are more numerous in some varieties than others. It is this twisted character of the fibre which is held chiefly responsible for the excellent spinning and weaving qualities of cotton, causing the fibres to lock themselves firmly together. These qualities are also affected by the length and fineness of the fibre.

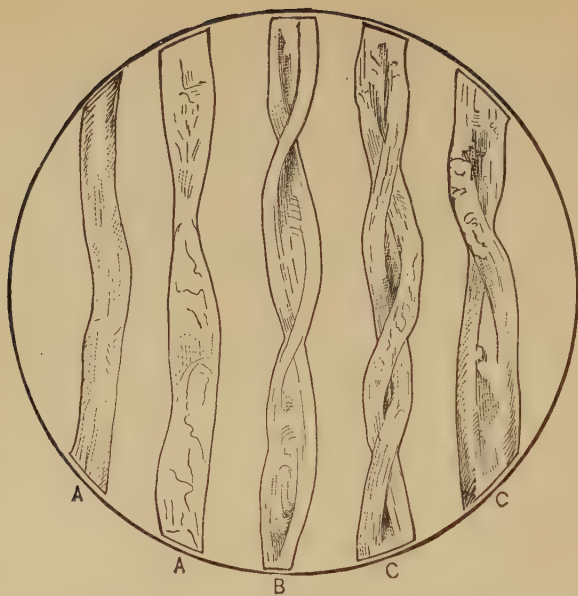


FIG. 15. Cotton Fibres—Longitudinal Views.

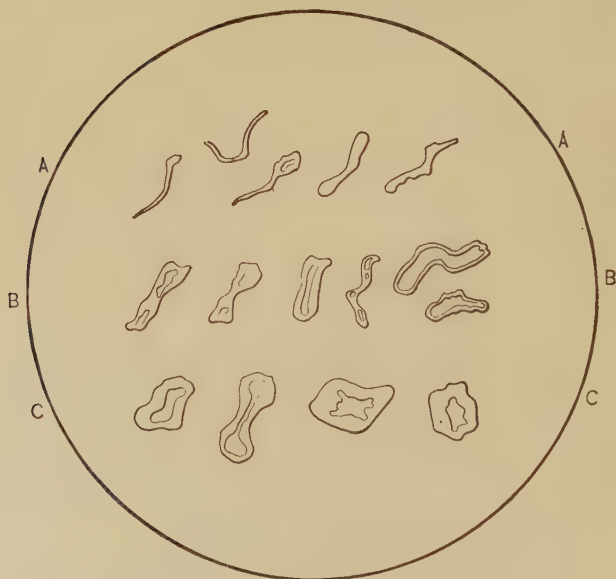


FIG. 16. Cotton Fibres Cross-section: A, A, Unripe Fibres; B, B, Half-ripe Fibres; C, C, Fully Ripe Fibres.

Wool

Wool is an animal fibre obtained from the animal of the order *Ruminantia*. The wool of commerce is the hair of the class *Ovidae* of which there are a number of species varying in geographical distribution, in form and shape and in the kind of wool obtained from them.

The three classes of *Ovidae* are:

(a) *Ovis aries*, or domestic sheep, cultivated in almost every country throughout the world.

(b) *Ovis musmon*, native to European and African countries bordering the Mediterranean sea.

(c) *Ovis ammon*, wild or mountain sheep of Asia and America.

By far the greater portion of the wool of commerce comes from the class *Ovis aries*, or domestic sheep.

Conditions of soil and climate, breeding, cross-breeding and intermixing have a great influence on the character and kind of wool produced. The original stocks domesticated are merino and mountain, from which have sprung the cross breeds and mixed breeds. The rank of the major geographical world units in wool production is as follows:

	<i>Pounds</i>
Australia	490,000,000
Argentina	270,000,000
United States	266,000,000
South Africa	185,000,000
New Zealand	180,000,000
Russia (European)	150,000,000
United Kingdom	102,000,000
Uruguay	90,000,000
Spain	88,000,000
British India	65,000,000
China	61,000,000
Turkey (Asiatic)	60,000,000
Italy	59,000,000
Germany	54,000,000
Roumania	53,000,000

World production by kinds was estimated by the "Market Reporter" in 1920 to be as follows:

	<i>Pounds</i>
Merino	869,000,000
Cross-bred	1,135,000,000
Low Wool	890,000,000

FLEECE WOOL is that cut from living sheep. It appears in the market as:

- | | | |
|---------------|---|--------------------------------------|
| (1) In grease | } | 1st cut—lambs wool |
| (2) Washed | | 2nd cut—hoggett |
| (3) Scoured | | 3rd and subsequent cuts—wether wool. |

SKIN WOOL is that removed from the skins of dead animals by the sweating process. The commercial terms are:

(1) Colonial Wool, when sodium sulphide method of de-wooling is used.

(2) Slipe, when de-wooled by the lime process, which results in a very inferior wool.

(3) Pulled wool, pulled by the roots from the pelts of dead sheep.

Other commercial terms encountered in the United States are:

Medium Wool, used for worsted goods.

Clothing Wool, used for broadcloth, heavy cloth and dress goods.

Delaine Wool, from the Ohio Merino and the finer crosses.

Territory Wool, from west of the Mississippi River.

Carpet Wool, coarse, hairy, lustre-less, non-wavy wool from Asia Minor, Persia, China, Russia and Argentina.

CHEMICAL COMPOSITION OF RAW WOOL

Wool is similar in chemical character to other epidermal tissues such as horn, hair and feathers. Raw wool, of course, contains substances which are foreign or extraneous to the actual fibre itself. These are:

(1) Wool grease or cholesterol, which comes from the fatty glands surrounding the hair follicles.

(2) Suint, the dried up perspiration adhering to the wool fibre.

Wright¹ gives the following analysis as typical of wool in the grease:

	<i>Per cent</i>
Moisture	16.90
Wool fat	16.68
Other fatty matter	0.42
Suint	10.30
Sand dried, etc.	3.62
Pure wool fibre	52.08

Pure wool fibre consists of carbon, hydrogen, oxygen, nitrogen and sulphur combined in the form of a complex compound called Keratine, a proteid. There is always some mineral matter present in wool fibre, the average being about 1 per cent, and sometimes pigment is present.

HYGROSCOPIC QUALITY

Wool absorbs moisture more readily than any other textile fibre. The amount of hygroscopic moisture will, of course, vary with the temperature and humidity of the surrounding air. Under average conditions the amount of hygroscopic moisture will be found between the limits 12 to 14 per cent.

¹ Journal Soc. Chem. Ind., 1909.

EFFECT OF MOISTURE ON PHYSICAL PROPERTIES OF WOOL

The strength of wool decreases with the hygroscopic moisture content, but there is an increase in elasticity. Woodmansey¹ gives the following figures for the effect of moisture on wool:

TABLE 36A.—WOOL, MOISTURE, STRENGTH AND ELONGATION.

Moisture Content, Per Cent	Average Strength of 5 (3") Warp Strips, in Pounds	Average Elongation before Rupture, Inches
0	188.4	1.225
3.0	185.8	1.525
5.5	172.4	1.800
7.5	161.0	1.875
8.7	158.4	2.150
10.54 (air dry)	156.3	2.670
33.0 (damp)	123.6	4.460
53.0 (wet)	130.7	4.530

The epidermal scales are responsible for wool's lack of lustre, its rather rough feel, its felting and spinning qualities.

LINEN—(*Flax*)

Linen is the fibre obtained from the flax plant whose botanical name is *Linum Usitatissimum*. The fibre is prepared from the plant by the process known as retting, which is a fermentation process resulting in the decomposition of the woody tissues surrounding the cellulose fibres. It is then dried and after a storage period is "scrutched." Scrutching consists of cleaning the fibre from the woody portions of the stems. The fibres are then carded or combed, spun into yarn, and then

¹ Jour. Soc. Dyers and Col., 1918.

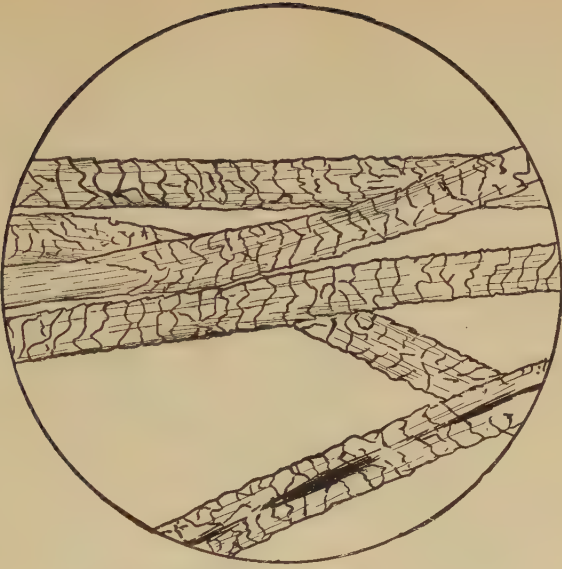


FIG. 17. Typical Wool Fibres after Removal of Grease.

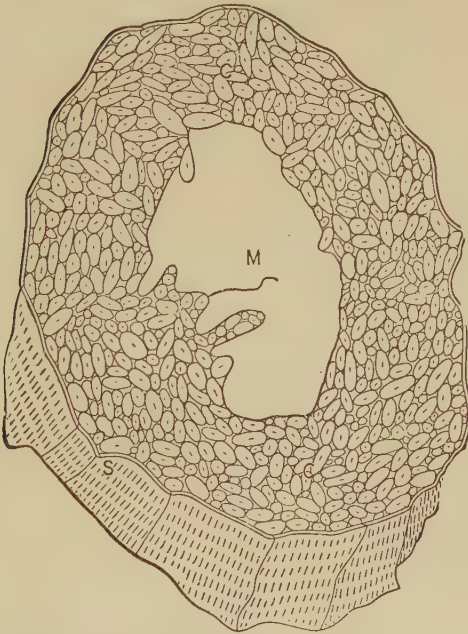


FIG. 18. Wool Fibre Structure Diagram: *M*, Marrow; *C*, Cells; *S*, Scales.

woven. Linen is perhaps the oldest known fabric. Mummy cloths of linen have been found which are over 4500 years old. The principal flax-growing countries are France, Ireland, Belgium, Holland, Russia, Japan, and Canada.

CHEMICAL CHARACTER

The flax fibre consists mainly of pure cellulose, a carbohydrate composed of carbon, hydrogen and oxygen. Other constituents are given by H. Mueller as follows:

	<i>Per Cent</i>
Hygroscopic water	8.65
Aqueous extract	3.65
Fat and wax	2.39
Cellulose	82.57
Mineral matter (ash)	0.70
Inter-cellular matter	2.74

Linen has about the same hygroscopic qualities as cotton. Under ordinary conditions of humidity and temperature the moisture content is from 6 per cent to 9 per cent. The strength of linen increases with its moisture content and it is a well known fact that linen is much easier to tear when dry than when wet.

Brun¹ gives the following table showing the effect of moisture on the strength of linen sail cloth:

TABLE 37.—EFFECT OF MOISTURE ON THE STRENGTH OF LINEN SAIL CLOTH

Moisture, Per Cent	Strength, Kilos	Moisture, Per Cent	Strength, Kilos
0.0	180	12.0	350
2.2	190	15.0	402
5.5	232	19.1	417
9.0	288	35.0	425

¹ Chem. Zeitung, 1893.

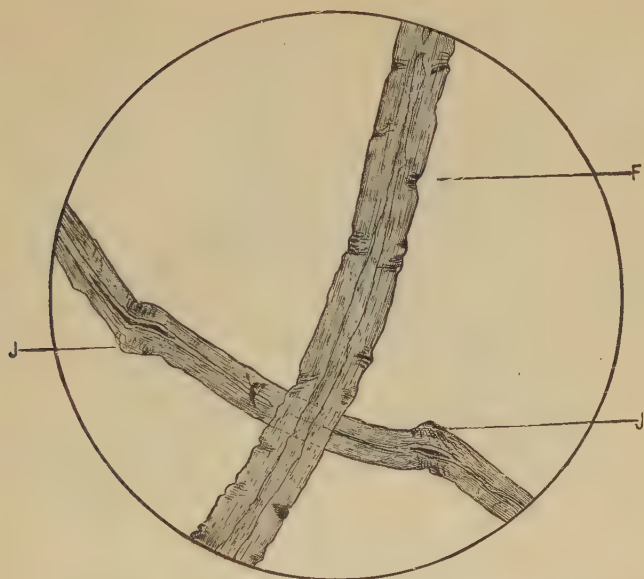


FIG. 19. Flax Fibre: *F*, Fissure-like Markings; *J*, Joint-like Formations.

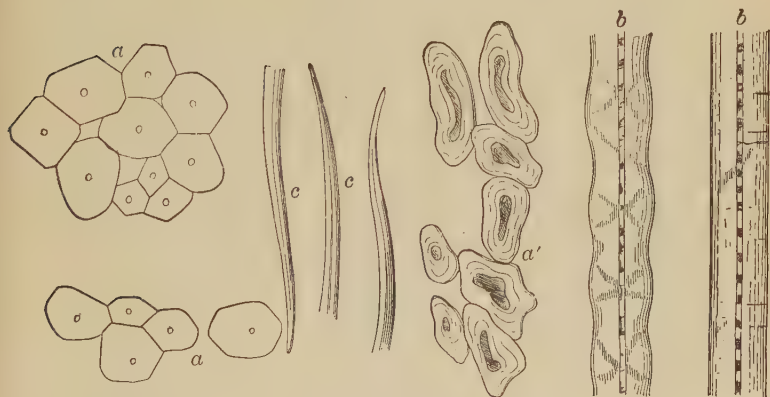


FIG. 20. Flax Fibres: *a*, *a*, Cross-sections; *b*, Longitudinal Views; *c*, Ends (Cross and Bevan.)

RAMIE

Ramie, or China grass fibre, is of two varieties, green and white, obtained from the nettles *Boehmeria Tenacissima* and *Boehmeria Nivea*. The use of ramie was known to the Chinese at a very early period, and it is also mentioned in the very early records of India, being called grass linen. Unlimited quantities of ramie are grown in Africa, India, China and Malay. The following table gives the chief physical properties of ramie as compared to linen, silk and cotton:

TABLE 38

	Ramie	Linen	Silk	Cotton
Tensile strength.....	100	25	13	12
Elasticity.....	100	66	400	100

PREPARATION OF RAMIE

Before it can be spun, ramie fibre must be separated from the stalk (decorticated) and de-gummed. The problem of decorticating cheaply in a mass production way is still unsolved and stands in the way of this fibre's more widespread adoption. In China and India decorticating is done altogether by hand, which is a slow and laborious process and is practicable only where labor may be had for a few cents per day. De-gumming is also quite troublesome. Carding, combing, spinning and weaving of ramie fibre offer no particular difficulties. An average analysis of ramie fibre is given by Mueller as follows:

TABLE 39. RAMIE FIBRE ANALYSIS

	Per Cent		Per Cent
Ash.....	2.87	Cellulose.....	78.07
Hygroscopic moisture....	9.05	Intercellular substance	
Aqueous extract.....	6.47	and pectin.....	6.10
Fat and wax.....	0.21		

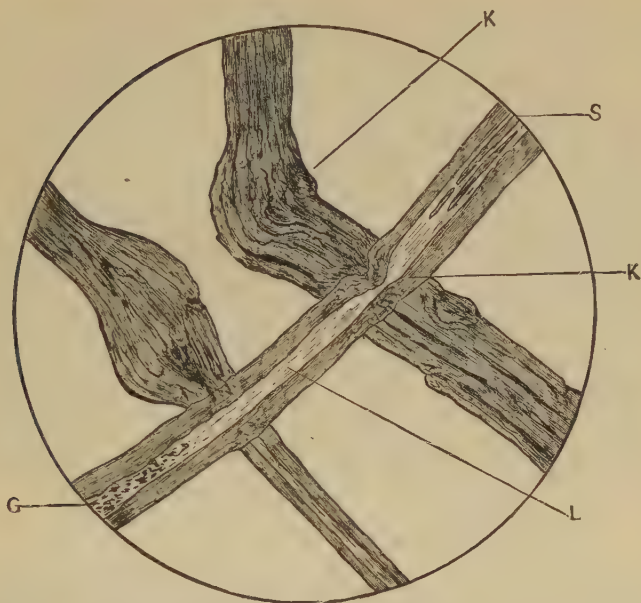


FIG. 21. Ramie Fibre: *L*, Lumen; *G*, Granular Matter in Lumen; *S*, Long Shreds of Matte in Lumen; *K*, Knots in Fibre.



FIG. 21A. Ramie Fibre: *a*, Sections; *b*, Longitudinal View; *c*, Ends, (Cross and Bevan)

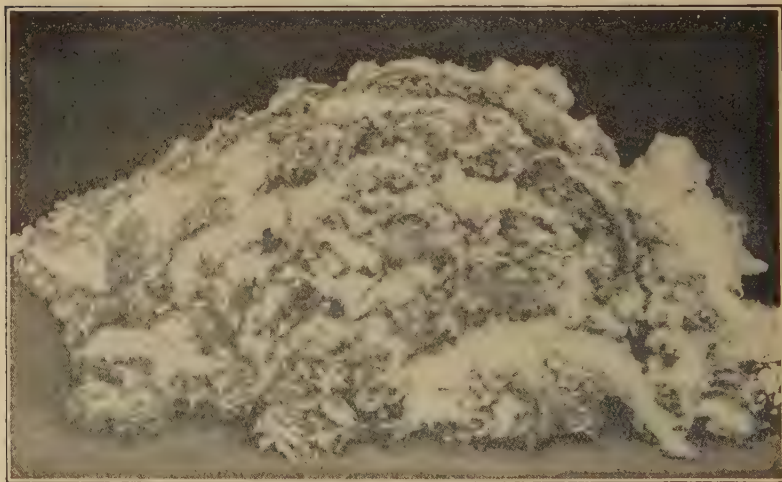


FIG. 22. Raw Materials.

Upper Picture—Spruce Logs Floating to Pulp Mill. (Courtesy International Paper Company.)

Cotton Linters in the Raw.

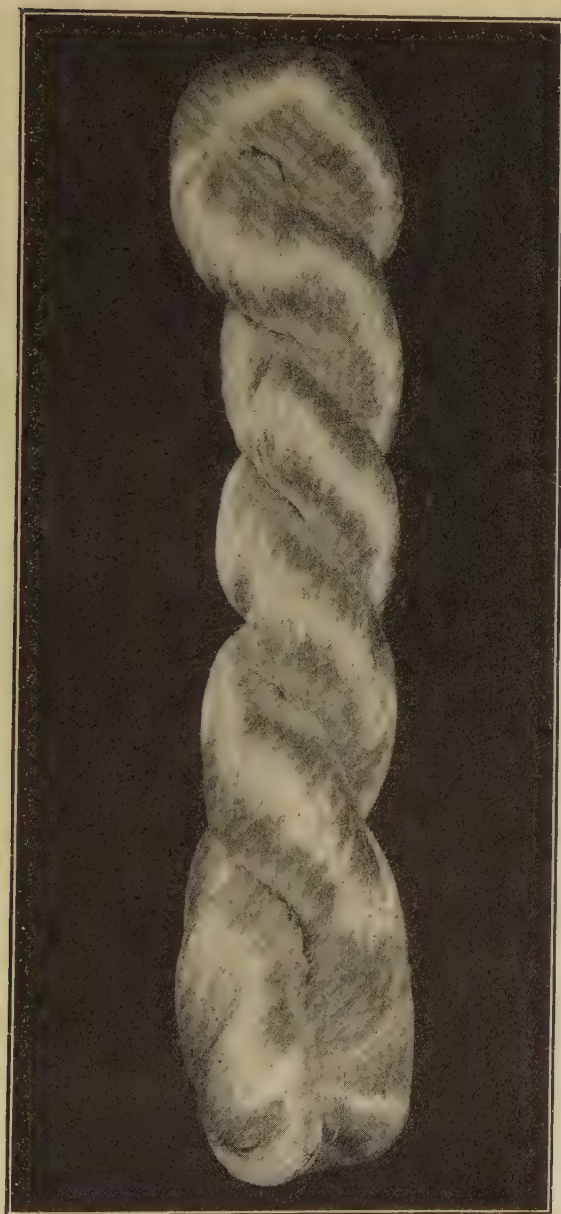


FIG. 23. Finished Rayon Yarn. Obtained from either Wood Pulp Fibre or Raw Cotton Linters.

The principal uses for ramie at present are for making gas mantels, and to blend with linen. This latter application results in a very satisfactory product of desirable quality. The hygroscopic qualities are very similar to linen, and ramie fibres are similarly affected in strength by moisture.

SILK

Silk is an animal fibre, produced by the silk worm, which winds it about itself in a continuous thread forming the cocoon. The length of the fibre in one cocoon varies from 350 to 1200 meters. The silk industry originated in China about 2700 B.C. In the beginning it was a secret of the Royal Family but gradually, however, silk production spread throughout the country. The art was a Chinese monopoly for about 3000 years. It next spread to Japan, then throughout Central Asia, and finally to Europe (in about the year A.D. 900).

Today seri-culture is being conducted to some extent in almost every civilized country of the globe. The silk worm is a species of caterpillar; the silk of commerce is mostly produced by *Bombyx mori*, or the mulberry silk worm. The *Bombyx mori* are of two classes—polyvoltine, which reproduce themselves several times a year, and annual, which have but one generation per year.

The stages of silk worm culture and cocoon production are briefly as follows:

The eggs are laid by the silk moth on cloths. These are then hung in rooms where a semi-saturated atmosphere is maintained for a few days. The rooms are then cooled (in many establishments by artificial refrigeration) and the eggs are allowed to hibernate for about six months. The eggs are then taken to heated hatching compartments in which the temperature is carefully regulated. Hatching requires about

30 days. On emergence from the egg state the caterpillars are about 3 millimeters long. They begin to devour mulberry leaves almost immediately and their growth and development is rapid. (See Fig. 17.) During the period from birth to maturity the silk worm sheds its skin four times. During the

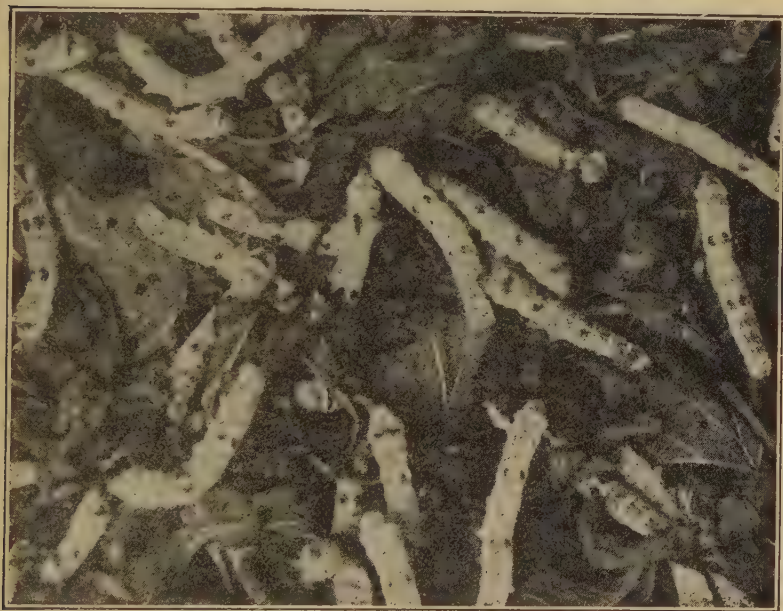


FIG. 24. Silk Worms Devouring Mulberry Leaves.

moulting of the skin the silk worm stops eating and is motionless.

The life history of the silk worm is divided into five periods, as follows:

Period	Stage	Time
First.....	Birth to first moult.....	5 to 6 days
Second....	First to second moult.....	4 days
Third.....	Second to third moult.....	4 to 5 days
Fourth....	Third to fourth moult.....	5 to 7 days
Fifth.....	Fourth moult to maturity....	7 to 12 days

The silk worm reaches its greatest size during the fifth period measuring 8 to 9 centimeters in length. It now ceases to eat and begins to diminish in size and weight. The worm then begins to form its cocoon, for which purpose it attaches itself to a convenient twig.

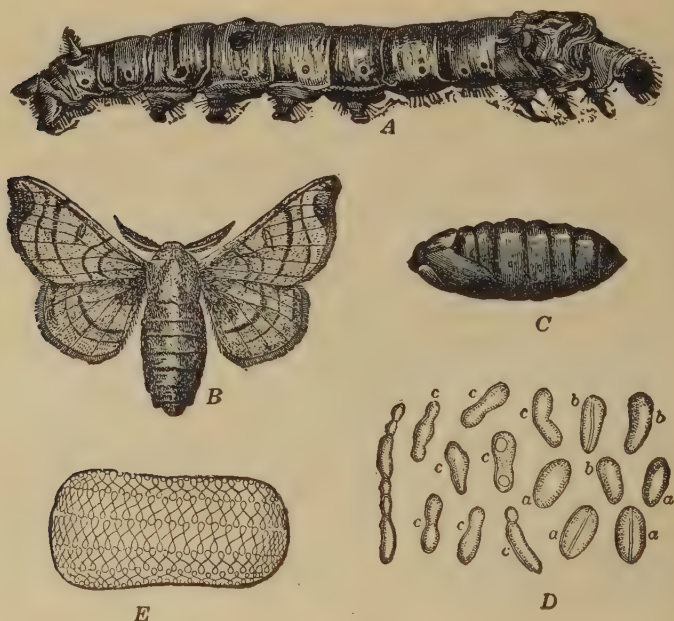


FIG. 25. Different Stages in Growth of Silk Worm: *A*, Silk Worm in Fifth Period, Full Size; *B*, Moth or Butterfly; *C*, Chrysalis; *D*, Eggs of Moth; *E*, Diagram Showing Cocoon and Method of Winding.

The silk secretion (fibroine) is formed in two posterior glands connected by channels to a common exit tube. Two anterior glands supply the silk glue (sericine) which cements the two fibres together. On emergence from the worm's spinneret head, the fibre is coagulated by contact with the air. By a figure eight motion of its head the silk worm builds up its cocoon, layer upon layer, until finally at the end of about 72 hours the silk worm is completely enclosed. The worm



FIG. 26. Feeding the Silkworms.

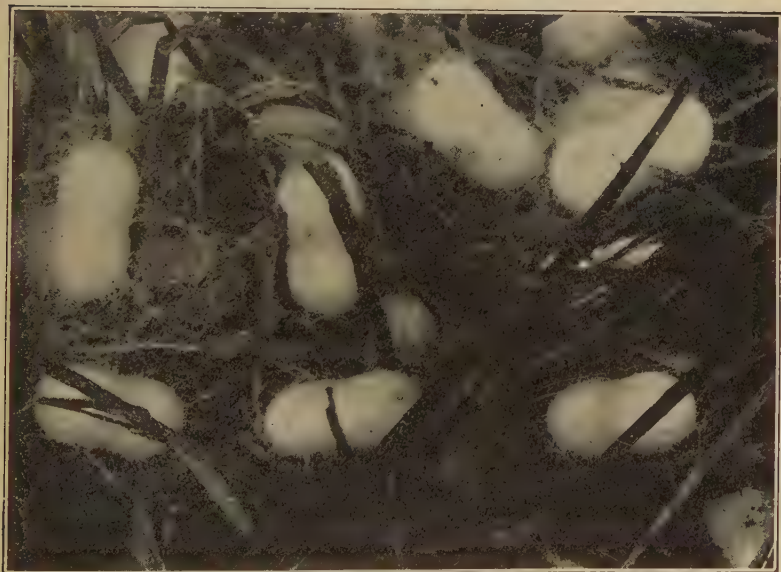


FIG. 27. Silk Worm Cocoons.

is now in the chrysalis or pupa stage from which it rapidly develops into a butterfly. As the cocoon is spun, the worm leaves one end less dense. The butterfly is provided with an alkaline secretion which softens this end, parting the thread and permitting the moth to escape.



FIG. 28. Sorting and Grading Cocoons.

In silk culture, of course, only a certain number of cocoons are permitted to develop to butterflies for purposes of reproduction, for the burst cocoon is of little value for silk production and can only be utilized for spun silk. The pupa or chrysalis stage lasts about two months and is stopped just before completion by exposing the cocoon to dry heat or live steam. Live steam is preferable for it helps to soften the silk gum which makes unreeling easier. After sorting and grading, the cocoons are unreeled, the fibres of about 5

cocoons being twisted together to form a thread, skeins of which are known as raw silk or grege. The waste resulting from unreeling, namely, short ends, broken and tangled fibres, cocoons from which the moth has escaped, are known as floss silk, which is used in making spun silk. According to Arbousset, one ounce of silk worm eggs will produce about 30,000



FIG. 29. Unreeling the Cocoons.

worms yielding a harvest of 130 to 140 pounds of cocoons from which approximately 12 pounds of raw silk can be reeled. This number of silk worms consumes about one ton of ripe mulberry leaves.

THE PRINCIPAL DIVISIONS OF THE SILK INDUSTRY

1. Sericulture, the growth and cultivation of the silk worm and the cocoon.
2. Silk reeling, the treatment and unreeling of the cocoon to form the skeins of raw silk.

THE RAYON INDUSTRY

3. Throwing, the throwster converts the raw silk into yarns suitable for the manufacture of fabrics.

4. Manufacturing, (a) weaving; (b) knitting; (c) braiding; (d) bleaching; (e) dyeing; (f) weighting.

Since reeling is a hand operation requiring patience, care and skill, it is carried on for the most part in such countries where this labor is cheap, namely, China, Japan and the Asiatic countries. While European countries do some reeling, it is quite likely that the filatures (silk reeling establishments) will decrease there due to the increasing cost and scarcity of labor.

Raw silk production in 1926 was divided approximately as follows:

	<i>Pounds</i>
Europe	7,360,000
Asia	80,960,000
Levant	4,000,000

HYGROSCOPIC PROPERTIES

Silk is very hygroscopic and will absorb up to 30 per cent of moisture and still have a dry feel and look. The average moisture content under ordinary conditions of temperature and humidity is about 9 per cent. In common with most animal fibres the strength and elasticity of silk decrease with increased moisture content.

CHEMICAL NATURE OF SILK

According to Richardson the following is an average for mulberry silk:

TABLE 40.—SILK ANALYSIS

	Per Cent		Per Cent
Water.....	12.50	Sericine.....	22.58
Fats.....	0.14	Fibroine.....	63.10
Resins	0.56	Mineral matter.....	1.12



FIG. 30. Silk Reeling in Japan.

Fibroine is a proteid having an average analysis, as follows:

	<i>Per cent</i>
Carbon	48.53
Hydrogen	6.43
Nitrogen	18.33
Oxygen	26.67

Fibroine is insoluble in hot water, ammonia, or solutions

of alkali carbonates. It is, however, dissolved by hot caustic soda.

Sericine is also a proteid of approximately the following compositions:

	<i>Per cent</i>
Carbon	45.00
Hydrogen	6.32
Nitrogen	17.14
Oxygen	31.54

Sericine is soluble in hot water, concentrated hydrochloric acid, potassium carbonate and hot soap solutions. Sericine is rendered insoluble by treatment with acetic acid.

PROPERTIES OF SILK

Silk is distinguished by its great strength and elasticity. Weighting diminishes both these qualities. The density of raw silk is about 1.35; that of boiled silk is about 1.25. In the pure unweighted state silk is therefore lighter than cotton, linen, rayon (which average about 1.50 in density and wool, which has a density of about 1.34. The so-called "scroop" of silk is a property unique to it. It is the characteristic crackling or rustling sound produced when the fibres are squeezed and pressed.

MARKET TERMINOLOGY

The product from unreeling the cocoons is called raw silk or "grege" and is classified according to origin as Japans, Cantons, Shanghais and Italians or Milans. Organzine, or warp silk, is made from first quality cocoons by lightly twisting 3 to 8 cocoon threads with a right-hand twist producing 60 to 80 turns per centimeter. Double and threefold organzine are made by twisting 2 or 3 of the singles together with a left-handed twist. Tram, or weft silk, is made from second

quality cocoons. It is soft and flat because it is not so highly twisted as organzine. The single tram is made up of 3 to 12 cocoon fibres without twisting. Double and triple trams



FIG. 31. Spinning Silk from Floss.

are made by loosely twisting 2 or 3 of the singles together. Spun silk is made from floss, which is composed of short and tangled fibres, waste, etc.

MICROSCOPY

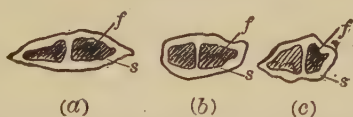


FIG. 32. Cross-section of Silk Fibre; *a*, from Inner Part of Cocoon; *b*, from Middle Layers; *c*, from Outer Part; *f*, Fibre of Fibroine; *s*, Layer of Sericine.



FIG. 33. Appearance of Raw Silk under the Microscope, Showing the Double Cocoon Filament and the Irregular Shreds of Silk-glue.

CHAPTER VII

TRADE ECONOMICS

TRADE NAME—SALES OF RAYON*—INTERNATIONAL TRADE ECONOMICS

IN this chapter the numerous questions relating to Trade Economics on Rayon, as they exist in the United States and in foreign countries, will be treated. For better consideration of the subject, this chapter is divided into three parts: (A) "The Trade Name and Sizes," (B) "Sales of Rayon," and (C) "International Trade Economics."

PART A: TRADE SIZES, QUALITIES AND TRADE NAME "RAYON"

The most widely used sizes of Rayon yarns on the market at the present time are 45, 60, 75, 90, 100, 150, 180, 200, 450, 600, 900, and 1200 deniers. The subject of the denier measuring system has been treated in Chapter V. Rayon yarns are offered as bleached and unbleached. The finer qualities are almost always bleached. In all classes and sizes of yarns (except the high denier from 450 up) three qualities "A," "B," and "C" were, until recently, distinguished in the trade. During 1928 two qualities of Rayon, that of the 1st and 2nd grade, were established. There are as yet no uniform standard specifications for the various grades, and each market quality is graded according to the production standards of the particular factory making them.

* Sales of Rayon by courtesy of Mr. Alexis Sommaripa, Manager Business Research, Dupont Rayon Co., Inc.

The usual *American "A"* quality is made up of the following number of filaments in the various counts:

<i>Denier</i>	<i>Filaments</i>
150	22, 24, 25, 30, 32, 36, 40, 42
170	24, 27, 60
200	30, 35, 60, 80
300	40, 42, 44, 50, 60
450	54, 60, 66, 72

Super-quality yarns are usually made up as follows:

<i>Denier</i>	<i>Filaments</i>
80	30
100	40
150	60

The present market basis is 150 denier first grade on the price of which all other sizes and qualities are based.

Since there exists a general effort to market this yarn formerly known as "Artificial Silk" under the generic word "Rayon," and since there are a few manufacturers that have not accepted the term "Rayon" for their product, it is essential in considering the marketing problems of Rayon yarn and yarn-made products, to indicate the reasons which lead to the adoption of the generic word "Rayon" and the agencies which have recommended its general use. On October 31, 1925 the Federal Trade Commission in Washington, D. C., released to the public the following information:

"The Federal Trade Commission by an official resolution has placed the stamp of its approval on the use of the word 'Rayon' as properly designating artificial silk products, the basis and chief ingredient of which is cellulose.

"There have been before the Commission a number of cases involving the misbranding of textiles which have artificially been given the appearance of silk, and have been sold under trade names containing the word 'silk' or a modification of the word 'silk.' In deciding these cases the Commission has consistently held that hosiery or other products which simulate silk but are not the product of the

cocoon of the silk worm should be branded with the words 'Artificial Silk' or other words which correctly describe the materials composing the article branded.

"The word 'Rayon' has been adopted by many associations of manufacturers as a proper one for artificial silk products and the term has been extensively advertised to the public. The Commission therefore believing that both the trade and the public have come to accept and recognize the word 'Rayon' as being applied to artificial silk or a substitute for silk, passed a formal resolution in which the term 'Rayon' is accepted as a proper designation for artificial silk products. The complete resolution follows:

"Whereas, A material has been developed, the basis of which is cellulose, which is extensively used in many trades and industries as a substitute for silk, to which material the term 'RAYON' has been applied; and

"Whereas, The said term 'RAYON' has been adopted by many different associations of manufacturers as the official and proper designation for artificial silk; and

"Whereas, The Federal Trade Commission in many decisions has consistently held that hosiery or other products made of materials which simulate silk but are not the product of the cocoon of the silk worm should be branded with the words 'ARTIFICIAL SILK' or other words which correctly describe the materials composing the article branded; and

"Whereas, The term 'RAYON' has been adopted by the trade, and is generally accepted and recognized by the trade and public to mean and indicate artificial silk, or a substitute for silk;

"Be It Resolved, That the Federal Trade Commission hereby recognizes the term 'RAYON' as meaning and properly designating the artificial silk products, the basis and chief ingredient of which is cellulose."

In the same way on August 18, 1928, the Better Business Bureau of New York City issued a Bulletin entitled "Important Facts about Rayon," which is given in its entirety hereinafter:

“Important Facts About Rayon: Although the first patents for the manufacture of Rayon (first termed artificial silk) were issued in 1884, to Reaumur and to Chardonnet, Rayon has since become the third textile in world production. Despite this fact there appears to be a lack of understanding of certain simple facts about this man-made textile.

“Contrary to a belief held by some people, rayon is not the trade-mark of any manufacturer or group of manufacturers. It is a generic word adopted by the trade, in 1924, to take the place of the negative and unsatisfactory names, ‘artificial silk’ and ‘fibre silk.’

“Rayon Has Been Defined: The new name quickly became popular and its general adoption was coincident with an increased use of the fibre. Following its successful use by manufacturers and retail advertisers, various branches of the Government gave their approval to the term.

“The Bureau of Standards of the United States Department of Commerce, for example, has published the following definition:

“Rayon—the generic name of filaments made from various solutions of modified cellulose by pressing or drawing the cellulose solution through an orifice and solidifying it in the form of a filament, or filaments, by means of some precipitating medium.”

“This definition has also been adopted by the Committee of Textiles (D-13) of the American Society for Testing Materials.

“The Federal Trade Commission, in an official resolution, has placed the stamp of its approval on the use of the term ‘Rayon,’ in the following words:

“The Federal Trade Commission hereby recognizes the term ‘Rayon’ as meaning and properly designating the artificial silk products, the basis and chief ingredient of which is cellulose.”

“All Varieties Are Rayon: It will be seen from the above that the term ‘Rayon’ is broad in its application; that minor differences in the method of manufacture, or even important differences, may exist and yet the resulting fibre is properly designated as Rayon.

“There are four types of basic chemical methods or proc-

esses used commercially in making Rayon, each producing a product somewhat different from the others:

1. Nitro cellulose or Chardonnet
2. Cuprammonium
3. Viscose
4. Cellulose acetate

Rayon Products and Trade Marks: Certain Rayon manufacturers have designated their products by trade mark or trade name. A few well-known examples are Celanese, Crown, DelRay, Bemberg, Glanzstoff, Lolustra, Premier, Rhodieseta and Tubize.

"The adoption of fanciful trade names to identify an individual maker's product is standard practice. This Bureau recommends, however, that the public always be informed that trademarked textiles are Rayon when such is the case, within the meanings enunciated by Government agencies.

"A statement made by any dealer or distributor, such as 'Bemberg is not Rayon' is inaccurate in the light of the definition of the United States Bureau of Standards. This is equally true of like statements about all other individual brand names of rayon fibre.

"Rayon is a distinct fibre just as wool, silk and cotton are distinct fibres. Rayon is a man-made fibre. To repeat, *an improved Rayon is still Rayon* just as a stronger, finer silk thread continues to be silk.

"Names That Denote Silk: This Bureau has recommended previously that rayon, being a distinct fibre, should not be described as 'Rayon Silk' or 'Silk Rayon.'

"If silk as well as Rayon is present in an article it is accurate to describe it as Rayon and silk; and it is desirable to adhere to this principle also when Rayon is combined with cotton, wool or linen.

"Certain fabrics have, through long usage, become associated with silk and might be said to imply silk. Their appropriation by another textile is not good practice. For example, the term 'Satin,' which designated a silk weave when originated, has been used in connection with all-silk fabrics for so many years that satin is generally understood to be of silk construction.

"This Bureau continues to recommend that when satin is not all silk, accuracy requires at least that the textile used in the weave be named, as, for example, 'Rayon Sport Satin.'

"Another term which denotes silk unless otherwise explained is velvet. A fabric of velvet weave but having a Rayon pile with silk back is better termed, 'Velvet: Rayon Pile, Silk Back' or where cotton is used instead of silk the description would read, 'Velvet: Rayon Pile, Cotton Back.' In the instance of so-called 'Transparent Velvet,' the Bureau recommends that 'Rayon' be included so the term will read, 'Transparent Rayon Velvet.'

"The terms 'Rayon satin,' 'Rayon pongee,' 'Rayon velvet,' 'Rayon foulard' and 'Rayon taffeta' show that a fabric is of Rayon content. This is not equally so with such examples as 'Celanese Satin,' 'Bemberg Taffeta' or 'Tubize Pongee.' For the public's complete information, the Bureau recommends that the word 'Rayon' be included as in these examples: 'Celanese Rayon Satin,' 'Bemberg Rayon Taffeta,' 'Tubize Rayon Pongee.'

"The Public Interest: The public is entitled to know the basic fibre as well as the trademark of a textile. Successful distributors have found that fully accurate descriptions make goods easier to sell and many are adhering to accuracy principles.

"Rayon is an attractive fibre which has much to commend it. Its sale does not require such claims as: 'Looks like silk; wears like silk, washes like silk, but is not silk.' Rayon can stand on its own feet without trading upon the good qualities and the established reputation of any other fibre. For years the products made and sold under this distinctive name have grown in favor with the public. The accurate use of this dignified name with proprietary names designating individual makers' products will conserve and increase public confidence in this important, man-made textile."

The Rayon Institute, realizing the value of recognition by the general public for this new synthetic textile, is using all its efforts to inform the public as to its properties, its adaptability and general merit when compared to the other natural textiles, and in order to propagate a universal knowledge of this product it is giving it carefully prepared publicity

under the newly created name "Rayon." The Institute along with the other agencies urge all producers of this cellulose yarn to adopt the name "Rayon."

We have thus established the reasons which have led these various authorities to recommend and in many instances to insist that all the producers of Rayon should use the word "Rayon" as a general term for this cellulose fibre. Irrespective, however, of this insistence on the part of the various agencies referred to, some of the producers of this yarn are not using the term "Rayon."

Among the important companies in the United States, the Viscose Company of America, the DuPont Rayon Company, the Industrial Rayon Corporation, the American Chatillon Corporation and a few other producers use the term "Rayon" as an adopted word for this man-made textile fibre just as the terms cotton, wool or silk represent the respective textiles which we all have learned to know under these latter names.

The American Bemberg Corporation, the Tubize Artificial Silk Company and the Celanese Corporation of America have not adopted the term "Rayon" for their product, but they use instead the trade name "Tubize Brand Yarn," "Celanese Brand Yarn" and "Bemberg Silk."

The companies which have not adopted the term "Rayon" feel that if the good and bad qualities of this synthetic fibre are purchased by the general public under the name of "Rayon," the producer of the low quality yarn would suffer at the hands of the producer of the low quality. Further, they also feel that it is difficult to create even for the high quality yarn a special market if all such yarn would be known as "Rayon," which is the reason for adopting the trade mark under their own name.

It is also claimed that the companies which have adopted the term "Rayon" sell their yarn to anybody or through any channels. They sell to the manufacturer of Rayon, to the converter or to the jobber. With a trade name or brand,

however, it is thought that no matter which way or through what medium the yarn is sold to the purchaser, it can always be traced back to the producer if the yarn has not proved right. Further, if the producer with a trade name wants to do national advertising based on high quality product any claim he makes for it can be traced to the producer. This is what the producer with a trade mark wishes to emphasize as the reason why they do not adopt the word "Rayon." They claim for instance that the American Woolen Company in selling its woolen cloth through all types of channels reaching finally the tailor, the credit for good or bad cloth can hardly be traced back to the American Woolen Company as any marks that appear on the whole bolt of cloth disappear with its being cut into suits. Hence any national publicity by the American Woolen Company may not do it very much good. These companies that adopted the trade name instead of the term "Rayon" are using the term "Brand Yarn" next to the name Tubize or Celanese, but they are not saying "Tubize Yarn Rayon," which would indicate to the ultimate buyer that the cloth, the wearing apparel or the hose he buys is made of cellulose solution.

The companies which do not use the word "Rayon" feel that they have an opportunity of giving effective publicity to their yarn under their trade name, and they will not take the chance in falling into the position where the Aspirin producers were when they had spent considerable money advertising their medical or pharmaceutical product. When later new companies started manufacturing the same product under the name "Aspirin" it was deemed necessary by the original group to sue these new producers in order to get redress and damages, but the court found that the continued publicity given "Aspirin" by the original manufacturers made it a general public name to the extent that it was included in the dictionary, which declared it public property. As a result of

this judgment, the original manufacturers to protect themselves had to create new trade names, by using the word "aspirin" in combination with the name of the manufacturers. It was thus that we have obtained the "Bayer's Aspirin." This may be given as one of the arguments why some of the companies are adhering to their own trade names.

Irrespective of this form of reasoning as to why the term "Rayon" is not used, the Viscose Company has recently adopted the term "Crown" for its trade name, but they are using it in combination with the word "Rayon" so that "Crown Rayon" represents the product of the Viscose Company of America. This was done for two reasons. One is to get away from the word Viscose which is a solution of the process which every Viscose Rayon producer uses, and also to create a new trade name owned exclusively by the Viscose Company of America and to which they can give general publicity.

The Du Pont Rayon Company uses the word Du Pont in combination with Rayon, thus giving the public their Rayon product under the trade name of "Du Pont Rayon." At the time, the Celanese Corporation of America announced that their celanese yarn would be marketed in the future as "Celanese" and not as "Celanese Rayon," the Du Pont Rayon Company made a statement which was issued on October 5, 1928 that they had decided to market their acetate product as "Rayon." Herewith follows the statement:

"Rayon yarns made by the cellulose-acetate process are now being imported and sold in this country by the duPont company. Similar yarns will be manufactured by this company in the near future, and while they will be given a trade name to distinguish them from yarns manufactured by other processes, these cellulose-acetate yarns will be advertised and sold as Rayon."

Since the above announcement was made the Du Pont

Rayon Company named the new DuPont acetate yarn "Acele" Rayon.

At the same time, the Viscose Company of America and the American Chatillon Corporation, who like the Du Pont Rayon Company are erecting plants for producing Rayon under the Cellulose-Acetate process have announced that their Acetate Rayon will be advertised and sold as Rayon.

The Industrial Rayon Corporation offers its Viscose product under the trade name of "Premier" Rayon.

The producers, therefore, who claim to have a product distinct and different have been loath to give up what is considered a special name for the general term "Rayon." However, this should not be a stumbling block, for Rayon, as explained above, can be given the brand names of the manufacturers, and these names will carry with them whatever ideas of superiority, exclusiveness and quality which the manufacturer has won during the years he has built up his reputation with his consumers. In other words, such terms as "Tubize" Rayon, "Celanese" Rayon, "Industrial" Rayon, "Snia" Rayon, etc., etc., may become market brands for particular outputs of the general product.

Hence it is hoped that it will not be long before all the Rayon producers in the United States and throughout the world, will adopt the word "Rayon," which in combination with the name of the company, so as to distinguish it from yarns produced by other processes or manufacturers, would create a reasonable, fair and proper trade mark.

PART B: SALES OF RAYON

BY ALEXIS SOMMARIPA, MANAGER OF BUSINESS RESEARCH,
DUPONT RAYON COMPANY

The population of the United States increased from 76,000,000 in 1900 to 120,000,000 in 1928. The per capita

purchasing power has rapidly grown since 1890. Prior to that period a great many people in this country did not always have the cloth and house-furnishings that they could use. The steady increase in purchasing power gave them the opportunity to buy a proper supply of textiles. It was the question of satisfying the need for various commodities more than

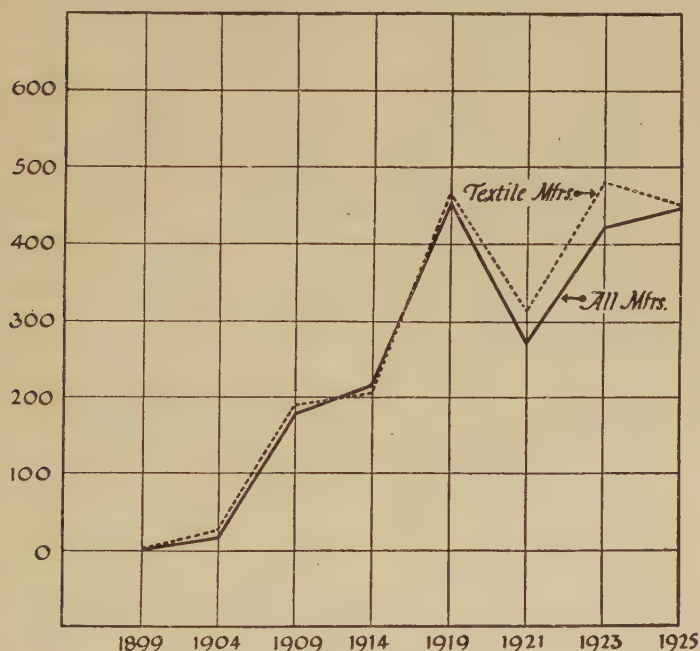


CHART 7. The Trend of Value of Textile Production as Compared to the Value of all Manufactures. 1899 taken as a base—100 per cent. Source: U. S. Census of Manufactures.

that of selecting the style merchandise. The sale of staple goods, therefore, was easy, which resulted in a huge increase in their production. During the twenty-year period, from 1899 to 1919, a 400 per cent increase was shown in the total value of textile production as indicated on Chart 7. A

corresponding increase in all manufactures has also taken place.

Since 1919 the total value of textile production continued to hold its importance in comparison with other manufactures. Various studies, conducted by government bureaus and private organizations, indicate that about 25 per cent of family budgets are still used for textile purposes. During the current decade, however, the increase of wealth has outrun the increase of population which stimulated the growth of the per capita purchasing power. The need for necessities having been satisfied, the demand for commodities with an appeal to the senses of luxury and tastes advanced at a more rapid rate than the demand for staple merchandise. A competition for the proportion of the consumer's dollar to be spent on various textiles became intense, irrespectively of the steady expansion of markets for them. This is due to the excessive capacity available to produce various textile wares. We see from Chart 8 that the production of silk, furs and knit goods increased since 1919 while the value of the total production of cotton and wool declined when 1925 is compared with 1923 or 1919. Since 1919 the total consumption of raw wool has shown a decided drop with the secular trend pointing downwards as shown on Chart 9. While the consumption trends of silk and of Rayon are distinctly pointing upwards, that of cotton, as indicated by Chart 9 is growing at a comparatively slow rate.

It must be remembered that the average annual income in this country per family is estimated to be less than \$2,000. This obviously results in a huge demand for an article such as the Chevrolet car which can satisfy the desire for luxury of the masses at a moderate price. Rayon fulfills the demand for attractiveness, style, slender body effects and ease in remaining fresh and clean, all of which are the main sales

appeals of silk. The French couture, which was first to capitalize these qualities of silk, gave the latter considerable im-

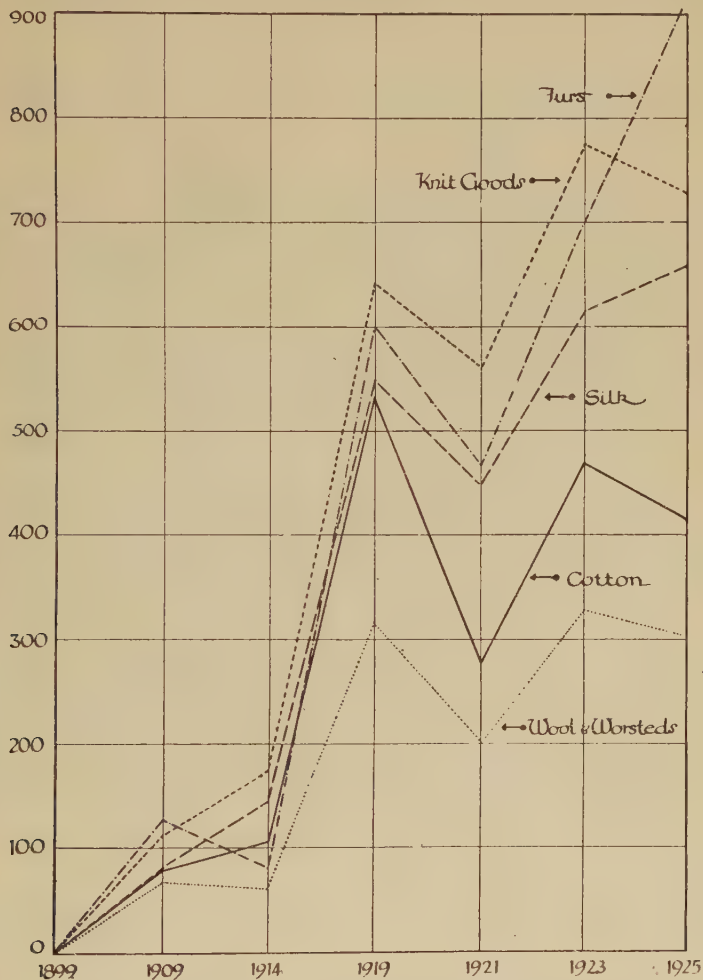


CHART 8. Index of the Trend of Value of Production of Different Textiles. 1899 taken as a base—100 per cent. Source: United States Census of Manufacturer.

petus and prestige. The world's style leaders are now utilizing the additional feeling of richness which can be produced by Rayon. The transparent velvets, the gorgeous Lunasol satin, the magnificent Rodier fabrics for interior decoration are all manifestations of the fact that Rayon, as the new medium of artistic textile expression, can produce sumptuous effects not obtainable with silk. Such uses, however, will give

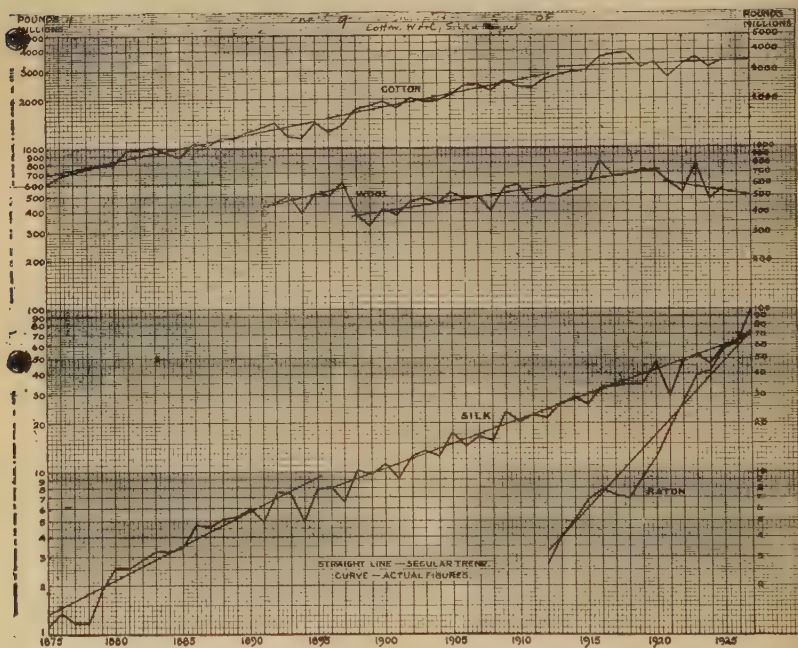


CHART 9. Consumption Trend of Cotton, Wool, Silk and Rayon.

Rayon the same feeling of prestige as heretofore went with silk, which has been associated with richness and nobility. On the other hand, when the limited few with large incomes accept a certain merchandise and buy it at high prices, the masses crave it. Rayon, indeed, is the textile which, al-

though accepted by the highest users, is also fully answering the luxury need of the masses. Table 41 gives the annual per capita consumption of Rayon in different countries.

TABLE 41.—PER CAPITA CONSUMPTION OF RAYON IN 1927

Switzerland.....	1 lb.—10.4 oz.
Belgium.....	1 lb.— 1.8 oz.
United States.....	13.6 oz.
Germany.....	11.5 oz.
England.....	10.7 oz.
India.....	10.3 oz.
Australia.....	8.6 oz.
Italy.....	6.6 oz.
Austria.....	6.1 oz.
France.....	6.1 oz.
Czecho-Slovakia.....	5.9 oz.
Holland.....	5.3 oz.
Japan.....	3.2 oz.
Spain.....	3.2 oz.
China.....	1.0 oz.
Poland.....	1.0 oz.

The production of Rayon is increasing at a very rapid rate. It has been estimated indeed by the Daily News Record that while the production of Rayon amounted to about 100,000,000 pounds in 1928, that it will amount to 128,000,000 in 1929, and 166,000,000 in 1930. The demand for Rayon yarn on the other hand has been increasing so far, at a rate rapid enough to absorb the available supply.

According to the figures released by the U. S. Census of Manufacturers for 1927 a 100% increase in consumption of Rayon was shown by the knit underwear and the cotton industries in comparison with 1925. An increase of 50% was shown in the silk industry, while hosiery increased its use of Rayon by one-third for the same periods.

The growth of Rayon consumption is due to the steady

increase in the demand for existing merchandise made with this fibre, as well as to the creation of new fabrics and new uses for them.

The figures below show the relative importance of Rayon in different industries:

TABLE 41A. FIBRE CONSUMPTION IN VARIOUS INDUSTRIES FOR 1927

(Source—U. S. Census of Manufacturers 1927)

	<i>Silk</i>	<i>Cotton</i>	<i>Wool</i>	<i>Knit Underwear</i>
	%	%	%	%
Rayon	21.8	.8	.2	10.4
Silk	58.7	.1	.3	.7
Cotton	15.8	98.8	14.2	82.0
Wool	1.1	.1	62.4	6.8
Other Yarns	2.6	.2	22.9	.1
Total Pounds	106,453,701	3,833,994,714	635,429,571	192,366,726

TABLE 41B

	<i>Hosiery</i>	<i>Knit Outerwear</i>	<i>Fibre Total of All Industries</i>
	%	%	%
Rayon	9.7	5.4	1.8
Silk	12.3	1.0	1.7
Cotton	72.8	30.7	84.2
Wool	3.7	62.8	9.1
Other Yarns	1.5	.1	3.2
Total Pounds	144,821,491	46,559,727	4,959,625,930

Although Rayon takes one-fifth of the fibre consumption of the silk industry and one-tenth of the knit underwear and hosiery, the proportion of Rayon of the total consumption of textiles in this country is only 1.8%. This is due to the fact that about 65% of the consumption of cotton which constitutes the bulk of textiles is put to industrial uses where the attractiveness, softness, richness and other qualities of Rayon are of little importance.

Rayon has also made little progress in the woolen industry, which is another important field of consumption of textile fibres.

PRICE TRENDS

TABLE 42.—AVERAGE YEARLY PRICES OF JAPANESE RAW SILK AND RAYON FROM 1913 TO 1927 INCLUSIVE

(*Textile World*, Sept., 1928)

Year	Japanese Raw Silk Filature, Shinshiu No. 13/15 Denier	Rayon, A Quality Bleached 150 Deniers	Absolute Differential
1913	\$3.7167	\$1.8500	\$1.8667
1914	3.6875	1.9625	1.7250
1915	3.3717	2.1250	1.2467
1916	5.0171	3.1125	1.9046
1917	5.6667	3.8625	1.8042
1918	6.4417	4.3968	2.0449
1919	9.2395	4.7666	4.4729
1920	9.0979	4.6625	4.4354
1921	6.1833	2.6708	3.5125
1922	7.3416	2.8000	4.5411
1923	8.2590	2.8000	5.4590
1924	6.2133	2.1125	4.1025
1925	6.495	2.0510	4.444
1926	6.20	1.750	4.450
1927	5.50	1.500	4.00

The figures have been reduced to comparison curves which are shown in the following Chart 10.

Rayon yarn is considerably cheaper than silk, nearly equal to the price of wool and about twice as expensive as cotton. The following quotations per pound for yarns of comparative weight give an idea of the price differentials:

Rayon ¹	\$1.50
Silk ²	5.00

¹ 150 denier, 24 filament, Viscose process, A grade.

² Japan filature, x 13/15 denier.

Yearly Average Prices Rayon v.s. Silk

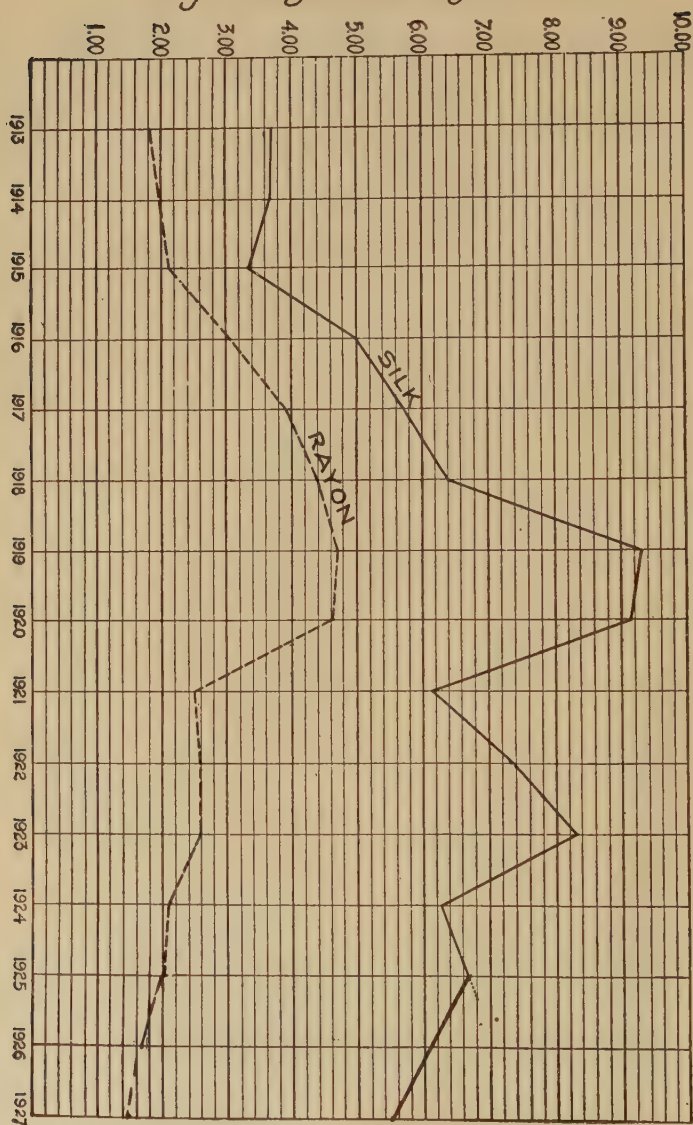


CHART 10. Chart Showing Comparative Curves of Average Yearly Prices of Rayon and Real Silk,

Worsted ³	1.65
Cotton ⁴	0.55
Mercerized Cotton ⁵	0.80

Since the writing of the manuscript, the price of Rayon had been reduced on February 25, 1929 and on June 18, 1929. The first reduction brought 150 denier from \$1.50 to \$1.30, and the second from \$1.30 to \$1.10. It is natural that the lower price of Rayon has put it in a better competitive position with other fibres. It is important, however, that in many instances, instead of reducing the price of the fabric, the leading textile manufacturers have improved the construction by putting more Rayon in it, and still sold the cloth at the old price. Due to the distinct shortage in fine deniers, they have been reduced proportionately less than the coarser deniers.

There are certain factors, however, which must be considered when a comparison is made between the price of Rayon and silk. As an example the size of silk yarns used more extensively is 13 to 15 or 20 to 22 deniers per individual thread. Three or five of these threads are usually combined together in making woven fabrics and as many as ten threads are put together in the manufacturing of hosiery. To produce fabrics of standard constructions, such as crepes or satins, it is necessary to use Rayon in sizes such as 100 denier or finer, which will be more comparable with those of silk but are higher in price than the regular 150 denier. The price of 100 denier of fine filament yarn, for instance, is \$2.25 per pound. The covering power of silk, however, is about 20 per cent greater than that of Rayon, which in itself would necessitate the use of 20 per cent more Rayon to obtain the same result. This advantage, on the other hand, is offset by the fact

³ Bradford System, ^s48/50, one-quarter blood.

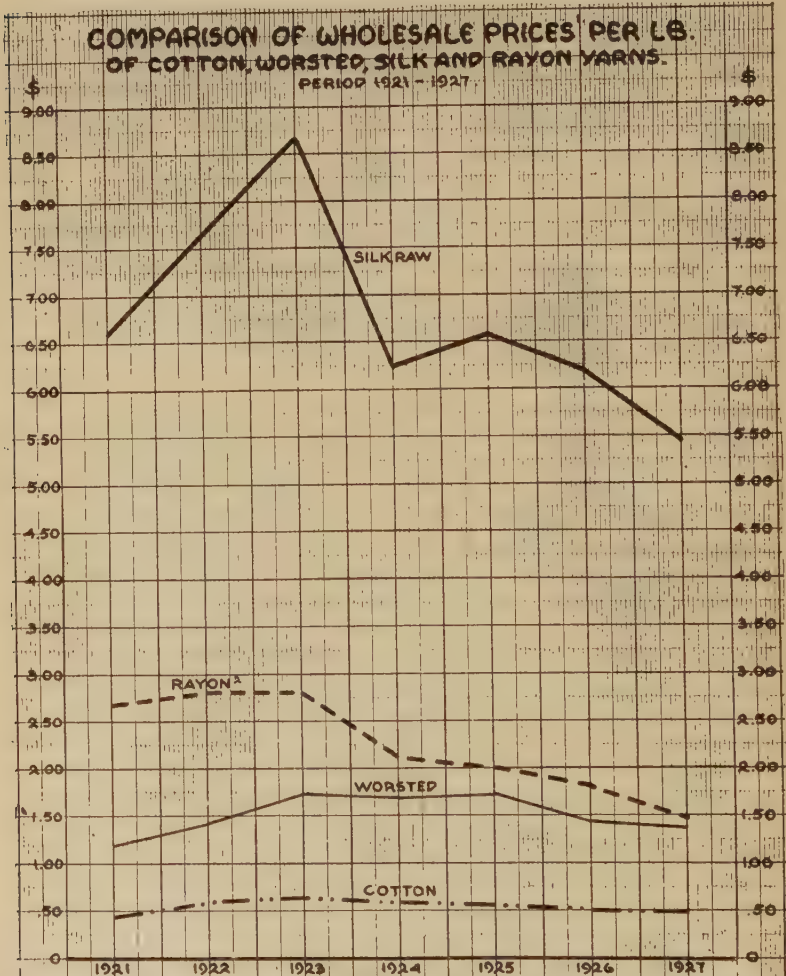
⁴ Peeler single cones, combed 36s.

⁵ Mercerized cones, combed ungassed.

THE RAYON INDUSTRY

that the silk quotation covers about 20 per cent of gum, which is totally lost in production of pure silk goods.

General comparison of price trends of different textiles is given in Charts 11 and 12. It should be observed that al-



^a All prices are averages of weekly quotations as compiled by the U.S. Dept. of Labor Bureau of Labor Statistics.
^b Representing average price of Bleached Rayon, 150 Denier, A grade, in the New York Market.

CHART II.

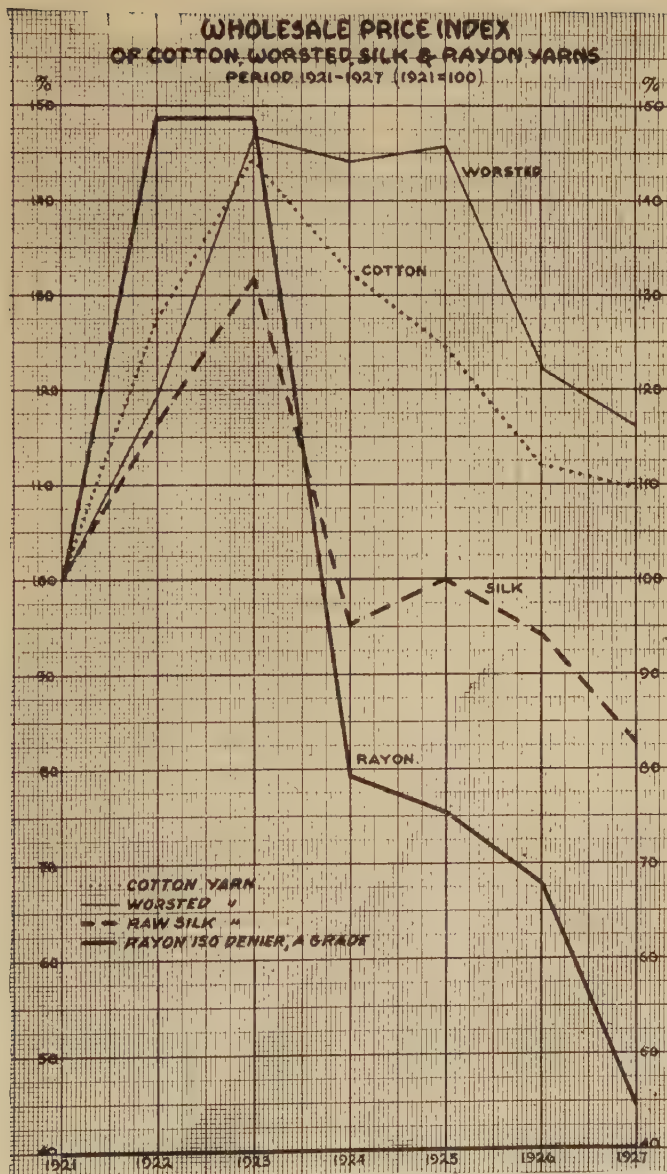


CHART 12.

though since 1923 the trends of prices of all textiles have been downward, the price of Rayon in 1927 was only 45 per cent of that of 1921 and the price of silk about 80 per cent while those of cotton and of wool have been higher, about 10 and 15 per cent respectively.

Additional light can be thrown on the relative prices of different textiles by studying their retail values. Thus the average price of printed cotton voile per yard was 67 cents while the average price of printed Rayon voiles was \$1.50. Printed cottons averaged 42 cents, printed Rayon alpacas 67 cents per yard. Rayon satin sold at about \$1.26 while plain silk satins were sold at about \$2.76. Plain silk crêpe-de-chine averaged \$2.17. All Rayon crepes, however, were successfully put on the market to retail at \$1.98. It may seem strange that the price of the Rayon crepes come so near to those of the silk ones. This is explained by the fact that a new quasi-textile is bridging the prices between the two. This is tin or other metallic salts which cost considerably less than a dollar a pound. There are certain fabrics on the market which being made only with one-quarter silk and three-quarters of low-priced adulterant, sell in direct competition with fabrics made of pure Rayon. The following quotations give the opinions of leaders in the dry goods business towards this type of merchandise:

The chief executive of the Retail Dry Goods Association warns that overloading, if too widely practiced will "pull down the pillars of the industry." Mr. Albert Blum, of the United Piece Dye Works, voices the opinion that to go beyond the safety point of 35 per cent in tin-weighting would eventually drive the women away from silk fabrics. General E. C. Young, president of the Belding-Hemingway Co., deplores the practice as injurious to the silk fibre, uneconomic, a deception, and therefore an unfair trade practice. He insists that tin in silk should be marked for public attention. Buyers for distributors are being advised to avoid heavily weighted goods and in this way discourage their production.

It may be of interest also to compare some prices of finished articles made of different textile material. The best selling prices in December, 1926, of knitted vests made of cotton was 50 cents, Rayon, \$1.00 and silk, \$1.95. The cotton bloomers sold at \$1.00, while those made of Rayon, \$1.95 and silk, \$2.95. For 50 cents more a woman was getting a Rayon vest which was dyed in an attractive color, was soft, comfortable and easier to wash than one of cotton. On the other hand, the Rayon vest was half the price of that of silk, and in accordance with the opinion of retail store buyers had style and color appeal equal to silk.

There is no question that the steady decline in the prices of Rayon which took place since it reached its high level in 1920 greatly facilitated the tremendous increase in its consumption as shown by Chart 13 on following page.

The prices of Rayon yarns vary with the Grade and Denier. The standard in the United States is 150 Denier Grade A* and Table 43 gives the New York prices for the standard yarn by months and years.

It is very likely that the reduction of prices in 1926 was responsible for the disposal of excessive stocks of yarn which accumulated during that year. The production in 1926, according to best estimates, was 62,000,000 pounds, of which 53,000,000 were sold, leaving additional stocks of about 9,000,000 pounds at the end of the year. In 1927, on the contrary, the sales were 85,000,000 pounds which was larger by 10,000,000 than the production of that year.

The lower prices of Rayon enabled the textile manufacturers to produce merchandise of better quality. When 150 denier was selling for \$2.00 it was difficult, for example, to make a Rayon vest of sufficient weight to be serviceable which could be retailed at \$1.00. The latter price, however, was the

* Since completing this volume the qualities of Rayon have been reduced to "first" and "second" grades instead of Grade "A," "B," and "C."

one at which the bulk of the business in this item had to be done. With the reduction of the price of the 150 denier to \$1.50, underwear of wonderful wearing qualities was immediately produced to retail at popular prices, the result being that the sales of women's Rayon underwear have shown a

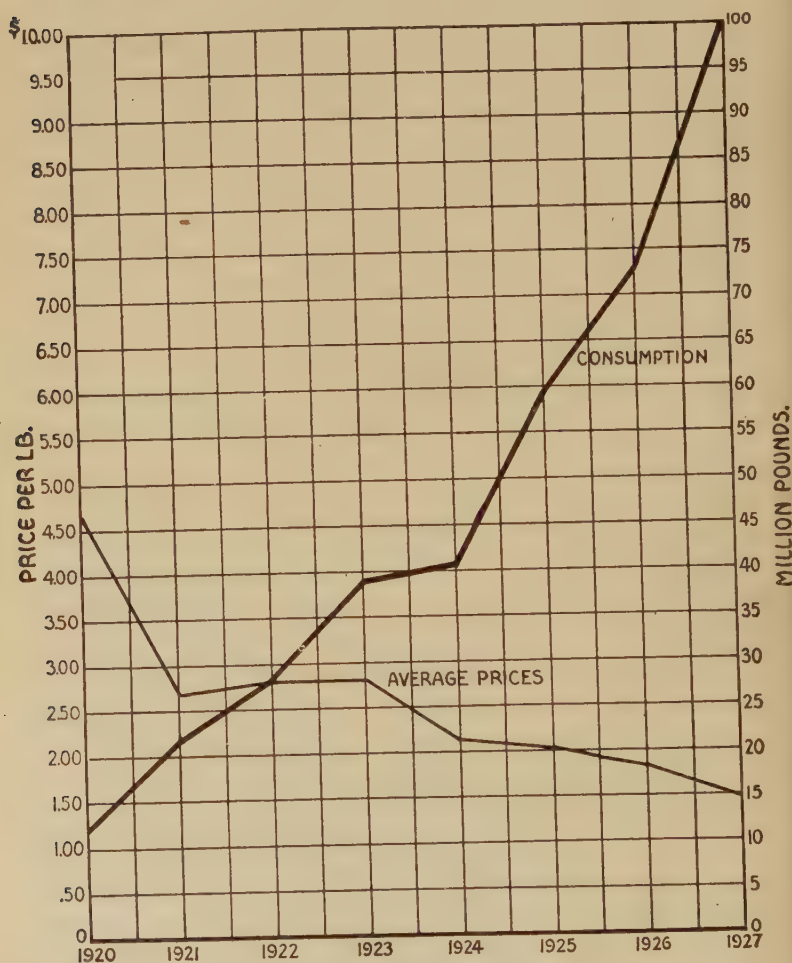


CHART 13. Prices of Rayon with Increased Consumption.

TABLE 43.—RAYON PRICE, 1915-1927, ON 150 DENIER A GRADE, NEW YORK

Month	1915	1916	1917	1918	1919	1920	1921
January.....	\$2.00	\$3.00	\$3.55	\$4.25	\$4.50	\$5.30	\$2.55
February.....	2.00	3.00	3.55	4.25	4.50	6.00	2.55
March.....	2.00	3.00	3.55	4.25	4.50	6.00	2.55
April.....	2.00	3.00	3.55	4.25	4.50	6.00	2.55
May.....	2.00	3.00	3.80	4.25	4.50	6.00	2.55
June.....	2.00	3.00	3.80	4.50	4.50	5.00	2.70
July.....	2.00	3.00	3.80	4.50	4.50	5.00	2.70
August.....	2.00	3.00	4.00	4.50	4.50	5.00	2.70
September.....	2.00	3.00	4.00	4.50	5.30	4.00	2.80
October.....	2.00	3.30	4.25	4.50	5.30	2.55	2.80
November.....	2.50	3.50	4.25	4.50	5.30	2.55	2.80
December.....	3.00	3.55	4.25	4.50	5.30	2.55	2.80
Monthly average.	\$2.13	\$3.11	\$3.86	\$4.40	\$4.77	\$4.66	\$2.67
	1922	1923	1924	1925	1926	1927- 1928	1929
January.....	\$2.80	\$2.80	\$2.80	\$2.05	\$2.00	\$1.45	\$1.50
February.....	2.80	2.80	2.05	2.00	2.00	1.45	1.30
March.....	2.80	2.80	2.05	2.00	2.00	1.50	1.30
April.....	2.80	2.80	2.05	2.00	2.00	1.50	1.30
May.....	2.80	2.80	2.05	2.00	2.00	1.50	1.30
June.....	2.80	2.80	2.05	2.00	2.00	1.50	1.10
July.....	2.80	2.80	2.05	2.00	1.65	1.50	1.10
August.....	2.80	2.80	2.05	2.00	1.65	1.50	1.10
September.....	2.80	2.80	2.05	2.00	1.65	1.50	1.10
October.....	2.80	2.80	2.05	2.00	1.65	1.50	
November.....	2.80	2.80	2.05	2.00	1.65	1.50	
December.....	2.80	2.80	2.05	2.00	1.65	1.50	
Monthly average.	\$2.80	\$2.80	\$2.11	\$2.00	\$1.81	\$1.49	\$1.96

remarkable growth. The linings for men's clothing is another interesting example. Rayon warp, cotton-filled satins and twills are sold now in a large way at prices lower than those of corresponding items containing silk and with far

superior wearing qualities. It was impossible several years ago to make a serviceable Rayon lining to be sold at reasonable prices.

The following Table 44 shows in detail the domestic prices for different types of Rayon as of October 26th, 1928. Rayon is made either with a standard number of filaments, which usually correspond to about 6.25 deniers per filament, or, of the fine filament variety. The latter is usually made with 2.5 deniers per filament, although it is also sold commercially with finer or coarser filaments. Since there are four processes by which Rayon is manufactured the prices are given separately.

The prices of cellulose-acetate yarns have undergone recently two reductions, bringing them to a par for certain deniers with the prices of viscose process yarn, as can be noted in Table 44.

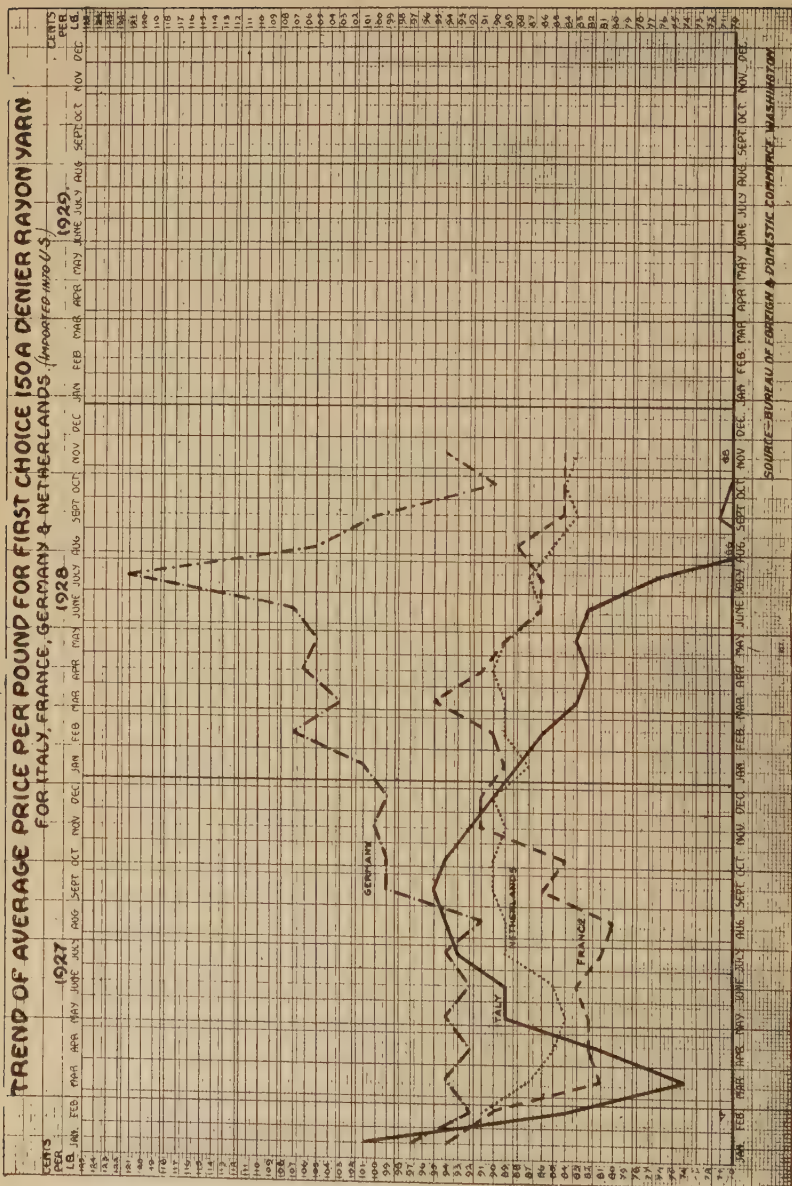
Considerable fluctuation has taken place in the prices of foreign yarns imported to this country, as shown by their landed values (duty not included) on Chart 14. It is of interest that since August, 1927 to 1929, the prices of German yarns have greatly increased. This is probably attributed to a larger importation of cupra-ammonium yarns. The landed values of Italian Rayons, however, have steadily declined since September of the same year, when they were 95 cents for 150 denier, A grade, to 66 cents for the same count in August, 1928.

In 1926, when the prices of Rayon were reduced there was a greater percentage drop in fine denier and fine filament yarn. The 150 denier regular with 24 filaments was, for instance, reduced from \$2.00 per pound to \$1.50 or 25 per cent; 150 denier with 60 filaments, on the other hand, declined 33 per cent from \$2.60 to \$1.75 and 100 denier 40 filaments was reduced from \$3.30 to \$2.25. The narrowing of the margin of prices between the fine denier and fine filament

TABLE 44. DOMESTIC RAYON PRICES PER POUND

Denier	Viscose				Acetate, 2½ Turns	Cupra- Ammonia	Nitro-Cellulose	
	Standard	Multi-Filament		Low Luster			A	B C
35	.....	.....	.....	.....	.....	.....	\$3.50	\$3.25
40	.....	.....	.....	.....	.....	.....	\$4.50	.....
45	.....	.....	.....	.....	\$3.00	.....	.....	.....
50	.....	.....	.....	.....	.....	.....	2.75	2.50
55	.....	.....	.....	.....	3.00	.....	.....	.....
60	.....	.....	.....	.....	.....	3.75	.....	.....
65	2.35	2.15	2.05	.....	.....	.....	.....	.....
75	2.55	.....	.....	.....	2.55	.....	2.50	2.30
80	.....	.....	.....	.....	.....	.....	.....	.....
85	2.15	2.00	1.90	.....	.....	3.60	.....	.....
90	2.30	2.15	2.05	.....	.....	.....	.....	.....
100	2.15	2.00	1.65	.....	2.40	3.25	2.15	2.00
120	1.80	1.70	1.60	.....	2.30	2.90	.....	.....
125	1.75	1.65	1.45	.....	.....	.....	1.75	1.65 \$1.50
130	1.70	1.60	1.50	.....	.....	.....	1.60	1.50 1.40
140	1.60	1.50	1.40	.....	.....	.....	1.50	1.45 1.35
150	1.50	1.45	1.35	A 1.75 (60*) \$1.35 A 1.60 (36*) \$1.35 C	1.90	2.40	1.45	1.30
160	1.45	1.40	1.30	.....	.....	.....	.....	.....
170	.....	.....	.....	.....	.....	.....	.....	.....
180	.....	.....	.....	.....	.....	.....	.....	.....
200	1.45	.....	1.25	.....	.....	2.30	.....	.....
240	.....	.....	.....	.....	.....	.....	.....	.....
250	1.35	1.30	1.25	.....	1.90	2.25	.....	.....
300	1.30	1.28	1.25	.....	.....	.....	.....	.....
450	1.25	1.20	1.15	.....	2.20	2.25	.....	.....
600	1.20	1.15	1.10	.....	.....	.....	.....	.....
900	1.25	1.20	1.15	.....	.....	.....	.....	.....
1200	1.20	1.15	1.10	.....	.....	.....	.....	.....

* Number of filaments in yarn.



yarn, and the coarser, regular yarn stimulated the use of the former and hence the production of better grades of fabrics, made possible by the finer Rayons, received a considerable spur.

Consumption of Various Types of Rayon Yarns

As indicated previously there are four processes by which Rayon is made. The United States Census of Manufacturers shows that of the total production of Rayon in 1927 of about 80,600,000 pounds, 70,600,000 pounds were of the Viscose type, the balance of 10,000,000 pounds, comprising nitro-cellulose acetate and cupra-ammonium Rayons.

Before discussing the uses to which the Rayons made by different processes are put, we will again review briefly the characteristics which are attributed to them even though there are differences of opinion on this subject.

The Viscose yarn has excellent running qualities and levelness of dyeing. It is even in denier and possesses good strength. It can be manufactured with a varied degree of lustre which ranges from a very low one to high sheen simulating metal.

The cellulose acetate has unique cross-dyeing properties; it absorbs only 5 per cent moisture while other Rayons under similar conditions would absorb 11 per cent. This is claimed to be an advantage when it is necessary to weave or knit the yarn on hot, muggy days. The dyeing of acetate is very level though the number of available colors is as yet limited. Fabrics made of this yarn have a very agreeable feel distinct from any other textile. Acetate is considered as having 10 per cent more true elasticity which results in less wrinkling of fabrics.

Fine deniers are made commercially and are known to run well in weaving. By applying heat in finishing, which to a certain extent melts acetate, permanent moiré

and ciré fabrics are made. Care must be exercised in ironing materials made of this yarn, particularly if they have been delustered. No acetone or chloroform should be used in dry-cleaning.

The nitro-cellulose process is well adapted to the making of fine deniers such as 35 and 50. Excellent crisp fabrics such as organdie, dimity and voiles for curtains are produced with this yarn, due to its somewhat inherent harshness. Fabrics made of this yarn have a sparkle in their luster which is an advantage for certain purposes. It has good knitting and weaving qualities.

Rayons made under the above three processes come either with the standard size filaments or with finer filaments being designated, in the latter case, as multi-filament yarns. The multi-filament yarn which was first put on the market and is now used most extensively is the super-extra quality made with $2\frac{1}{2}$ denier per filament. The multi-filament yarn is softer and stronger than the regular Rayon. It has better covering power and draping qualities. If the Rayon yarn is made of filaments of not much less than $2\frac{1}{2}$ deniers per filament, it has excellent running qualities.

The cupra-ammonium yarn is made with a subdued luster which is hard to distinguish from silk. It also has the scroop of silk. It is claimed, therefore, that this yarn is almost a replica of silk. Being made always with a multi-filament yarn of about 1.3 deniers per filament it has the characteristics mentioned above of fine filament yarns, namely the softness, covering power and drape. This yarn is equal to the strongest of Rayons, dry or wet, and for that reason withstands well the strain of knitting in full-fashioned hosiery.

It is generally considered that about half of the cellulose-acetate production is consumed in the manufacturing of voiles. There are also large quantities of satins and moirés that are made from it entirely or in combinations with other

Rayons. It is used as warp in crepes and crepe satins. Its cross-dyeing characteristics are utilized in manufacturing of brocades, fancy dress goods and men's hosiery. Nitro-cellulose is largely used in the knitted outerwear, underwear and hosiery. It is also utilized to a great advantage in the manufacturing of sheer dress fabrics. The cupra-ammonium yarn has its main outlet in full-fashioned hosiery, neckties, scarfs and shirtings. The 150 multi-filament Viscose process yarn is extensively used in better kind of knitted underwear. It is also consumed in large quantities for dress-goods, scarfs and hosiery. The 100-denier multi-filament yarn is responsible for the creation of the transparent velvet, all Rayon crêpes, Rayon and cotton radiums, high-grade satins and combinations of Rayon with wool. The 75- and 80-denier yarns are used in the manufacturing of voiles, georgettes, satins, etc.

It was estimated that in 1927, 75 per cent of Rayon production was in 150 denier, 11 per cent in 300 denier and 14 per cent in other sizes. In 1924, however, 24 per cent of the production was 300 denier, thus indicating that in previous years the consumption of heavier yarn in coarser goods was of greater relative importance. It is well known that the production of fine denier and fine filament yarn is not only large at present but is also steadily growing and in 1928 was larger than at any previous time in the history of Rayon production. There are many high-grade fabrics, indeed, being put on the market which are made entirely of finer Rayon. The chart on importations proves the same fact.

CONSUMPTION OF RAYON BY DIFFERENT INDUSTRIES

The discussion of the consumption of Rayon by the different industries will be based upon the consumption of regular Viscose process yarns.

THE RAYON INDUSTRY

TABLE 45.—CONSUMPTION OF RAYON BY INDUSTRIES, 1912-1927, POUNDS

	1912	1913	1914	1915
Hosiery.....	810,000	1,861,200	2,424,200	4,472,000
Knit.....	189,000	118,800	154,800	344,000
Silk.....	270,000	475,200	619,200	344,000
Cotton.....	270,000	554,400	722,400	1,032,000
Braid.....	270,000	118,800	154,800	137,600
Upholstery.....	81,000	79,200	103,200	137,600
Plush.....	405,000	594,000	774,000	206,400
Wool.....	81,000	79,200	103,200	137,600
Miscellaneous.....	324,000	79,200	103,200	68,800
	1916	1917	1918	1919
Hosiery.....	4,368,000	3,240,000	2,436,000	2,612,400
Knit.....	858,000	1,080,000	1,035,300	1,586,000
Silk.....	702,000	1,080,000	1,096,200	1,679,400
Cotton.....	936,000	936,000	791,700	1,212,900
Underwear.....	.....	.....	.....	93,300
Braid.....	234,000	288,000	304,500	1,212,900
Upholstery.....	156,000	144,000	121,800	186,600
Plush.....	312,000	216,000	121,800	279,900
Wool.....	78,000	72,000	.....	93,300
Miscellaneous.....	156,000	144,000	182,700	373,200
	1920	1921	1922	1923
Hosiery.....	3,025,000	4,289,500	6,516,000	8,668,000
Knit.....	2,541,000	5,408,500	7,059,000	9,850,000
Silk.....	1,573,000	2,238,000	2,986,500	5,910,000
Cotton.....	1,210,000	1,678,500	2,715,000	4,334,000
Underwear.....	121,000	373,000	1,086,000	1,970,000
Braid.....	1,694,000	1,865,000	2,986,500	3,240,000
Upholstery.....	242,000	373,000	543,000	788,000
Plush.....	363,000	271,000	186,500	788,000
Wool.....	121,000	186,500	271,000	394,000
Miscellaneous.....	1,210,000	2,051,500	2,715,000	2,758,000
	1924	1925	1926	1927
Hosiery.....	9,049,947	15,105,873	15,229,528	21,187,530
Knit.....	5,631,078	3,485,970	2,220,973	4,035,720
Silk.....	7,441,068	9,586,419	8,566,610	14,125,020
Cotton.....	6,234,408	14,815,375	14,277,683	22,700,925
Underwear.....	4,022,199	6,971,941	15,229,528	29,258,970
Braid.....	.....	.....	951,845	2,017,860
Wool.....	402,220	151,059	634,564	1,008,930
Miscellaneous.....	7,441,068	7,552,936	6,345,636	6,558,045

At the beginning of the Rayon industry in this country in 1913, the hosiery industry was its major outlet. Up to 1918 this industry took annually from 40 per cent to 65 per cent of the total Rayon consumption. From that year it showed a steady decline in its relative importance, dropping to 21 per cent in 1927. A most remarkable increase, on the other hand since 1919 was shown in the consumption of the underwear industry. From 1 per cent in that year it increased to 11 per cent in 1924; to 29 per cent in 1927, and in 1928 it was probably taking about 35 per cent of the total Rayon consumption. From Tables 45, 46 and 47, other interesting changes can be observed; braids, and knitted outerwear,

TABLE 46.—CONSUMPTION OF RAYON BY INDUSTRIES, PERCENTAGE

	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927
Hosiery.....	40	47	65	56	45	40	28	25	23	23	22	22½	12	24	21
Knit goods.....	5	3	5	11	15	17	17	21	29	26	25	14	6	3½	4
Silk goods.....	10	12	5	9	15	18	18	13	12	11	15	18½	16½	13½	14
Cotton goods...	12	14	15	12	13	13	13	10	9	10	11	15½	25½	22½	22½
Underwear.....							1	1	2	4	5	10	12	24	29
Braids.....	5	5	2	3	4	5	13	14	10	11	10			1½	2
Upholstery.....	5	5	2	2	2	2	2	2	2	2	2				
Plush.....	15	15	3	4	3	2	3	3	1	1	2				
Wool goods.....	3	3	2	1	1		1	1	1	1	1	1	1	1	1
Miscellaneous...	5	5	1	2	2	3	4	10	11	10	7	18½	13	10	6½

TABLE 47.—COMPARATIVE IMPORTANCE OF CONSUMING TRADES

	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927
Hosiery.....	1	1	1	1	1	1	1	1	2	2	2	1	3	1	3
Cotton goods...	3	3	2	2	4	4	5	5	5	5	4	3	1	3	2
Silk goods.....	4	4	4	4	3	2	2	4	3	3	3	2	2	4	4
Underwear.....							8	8	6	6	6	5	4	2	1
Knit goods.....	5	5	3	3	2	3	3	2	1	1	1	4	5	5	5
Upholstery.....	6	6	6	7	7	6	7	7	7	7	7				
Braids.....	7	7	7	6	5	5	4	3	4	4	5			6	6
Wool goods.....	8	8	8	8	8	8	9	9	9	9	9	6	6	7	7
Plush.....	2	2	5	5	6	7	8	6	8	8	8				

which from 1920 to 1923 took together more than a third of the Rayon produced, consumed only 6 per cent of it in 1927. The cotton industry, which up to 1924 averaged around 12 per cent, increased in 1925 to 25½, and is maintaining its position as the second largest in the consumption of Rayon.

Table 46 is a percentage table and while the figures run, in some cases, quite level, yet when we bear in mind the increase in production from year to year, the showing on the whole is one of steady growth in poundage in every field.

This, as indicated before, was made possible by the development of new fabrics and new uses in almost every industry. The reduction of price has also unquestionably greatly stimulated the use of Rayon. Not only its competitive position in comparison with other fibres has been improved, but also for the same price of a finished article, a much better construction was made available. The sales of Rayon containing fabrics are constantly receiving an additional stimuli through the improvement of the yarn itself, which results in greater operative economies and better products. It is really remarkable to see that each year brings on the market cloths made with Rayon which are better than the fabrics created during the previous year. The better cloths displace the cheaper constructions, as for instance Rayon alpacas have been superseded by Rayon and cotton radiums, and the latter by the Rayon and cotton crêpes. The Rayon yarn manufacturers are cooperating with the leading houses in developing new fabrics and in finding new uses for standard cloths.

CONSUMPTION OF RAYON BY THE SILK INDUSTRY

In 1927 approximately 16,000,000 pounds of Rayon were used by the silk and velvet industry. This compares with a consumption of about 60,000,000 pounds of silk, 15,000,000

pounds of cotton, and 3,000,000 pounds of wool, in 1925. There were in that year about 40,000,000 pounds of cloth produced entirely of silks, and 17,000,000 pounds of cloth made of mixed fibres. The comparatively small consumption of Rayon is explained by the fact that up to 1928 it was not used in crêped fabrics. Crêped cloths, however, constitute, at present, the bulk of the production of silk goods, amounting probably to about 75 per cent. More than one-half of the Rayon consumed by the silk industry was in combination with silk, the fabrics being mostly satins for women's slips and linings, taffetas for decorative purposes, as well as velvets and brocades. The bulk of the balance of Rayon was used in lining fabrics, in combination with cotton, and in dress and coatings together with wool. The materials made entirely of Rayon came last in order of importance, being mostly novelties, and cloths used for ties and scarfs. Since the beginning of 1928, staple constructions, such as crepes and crepe-back satins made entirely of Rayon were put on the market in a large way. Such cloths will make it possible for women of lesser means to use more extensively silk-like dresses instead of the ones made of cotton of the so-called house-dress type.

The sales of plain satins and twills containing Rayon have shown a 50 per cent increase in their relative importance in the spring of 1928 as compared with the spring and summer of 1927. This, and the fact that Rayon and wool mixtures have been somewhat stable, can be observed from Chart 15 which is based on reports from silk goods departments of 93 retail stores. Rayon transparent velvets amounted to 10 per cent from August 1 to November 1, 1928, in a similar group of representative stores. The transparent velvets are unquestionably creating prestige for Rayon in general, as they sell at higher prices than the sheer silk velvets. These fabrics, moreover, are of greater relative importance in exclusive

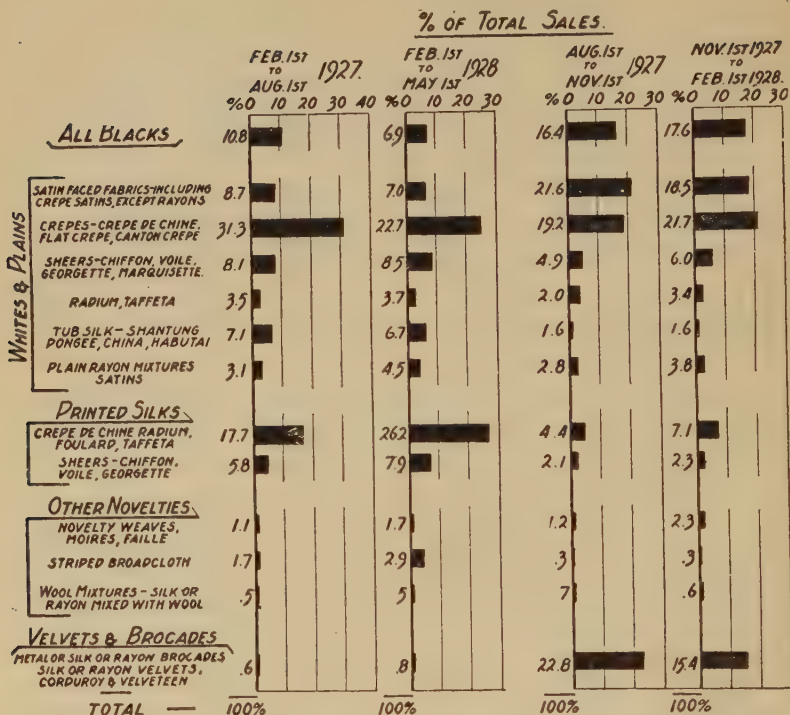


CHART 15. Comparison of the Relative Value of Sales of Different Fabrics—Total Sales in Dollars of the Silk Department for each Period taken as 100 Per Cent. Reports from Silk Goods Departments of 93 Retail Stores in 24 Cities in 21 States. By Alexis Sommaripa, from Trend of Sales of Rayon, Silk and Cotton in Piece Goods Department.

stores, and in larger cities, which indicates that they reach the highest class of consumer.

Though the consumption of Rayon in pounds by the silk industry is not as important as that of the cotton or underwear industries, it is very significant from the point of view of style and prestige. The silk industry, indeed, is proportionately using more fine deniers and fine filament yarns, which it utilizes in creating fabrics which retail at much

higher prices per unit than the Rayon products of other industries.

CONSUMPTION OF RAYON BY COTTON MILLS

In 1927 cotton weavers consumed approximately 23,000,000 pounds of Rayon. This seems to be a small figure when compared with 2,000,000,000 pounds of cloth which has been woven by them in 1925. The author estimates, however, that the latter figure comprised 1,300,000,000 pounds of cloth which was used for industrial or strictly utilitarian purposes where attractiveness is of little importance. The balance was made up of 500,000,000 pounds of fabrics used for wearing apparel, and 200,000,000 pounds intended for interior decoration.

The U. S. census of 1919 also shows that only 160,000,000 pounds of cotton yarns were made finer than 41s, while approximately 1,100,000,000 pounds of yarn were coarser than 20s, and 1,100,000,000 were medium sized yarns between 21s and 40s.

It is quite clear that at present there is little likelihood that Rayon will find an outlet in filter-cloths, bags, automobile tires, shoe-linings, etc.; which are the types of fabrics constituting roughly 65 per cent of cotton cloths. Rayon has a much better chance in women's and children's dresses, in underwear, shirtings and linings. It is making, indeed, steady progress in these fields. In the sales of the wash-goods departments of retail stores, for instance, where fabrics for such purposes are sold at retail, Rayon-containing cloths are showing a rapid increase. The Chart 16 indicates, for example, that while, from February to August of 1927, this group of cloths took 24 per cent of the total value of the wash-goods sales; from February to May of 1928, it amounted to 31 per cent.

It is of great interest that, as in the case of the silk industry, the cotton industry is producing fabrics made entirely

of Rayon. The all-Rayon voiles and satins, indeed, are the items which have shown the most rapid growth. These materials, moreover, as indicated on Chart 17, were of larger relative importance in exclusive stores and large cities, which

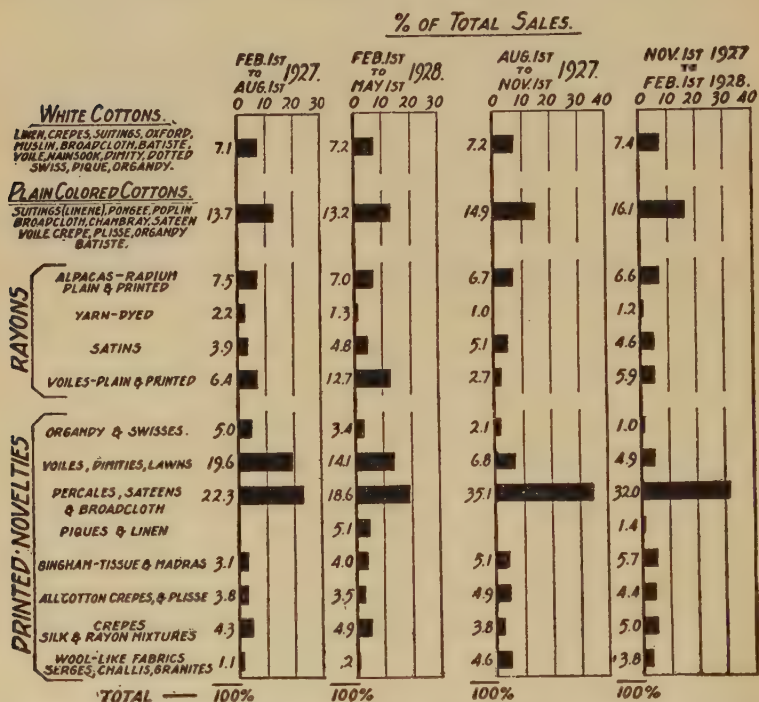


CHART 16. Comparison of the Relative Value of Sales of Different Fabrics—Total Sales in Dollars of the Wash Goods Department for each Period taken as 100 Per Cent. Reports from "Wash Goods" Department of 95 Retail Stores in 42 Cities in 21 States.

shows that they have taken well with the most exacting consumers. The small cities and the popular priced stores will undoubtedly follow this lead.

In interior decoration, which is the third group mentioned above, Rayon is also showing steady gains. It is estimated

that of the total value of sales of Upholstery and Drapery Departments of retail stores, Rayon-containing fabrics comprise 39 per cent. The sheer Rayons used for casement cloths takes 7 per cent, the damasks 24 per cent, the plain and striped taffettas 6 per cent, and satins and reps 2 per cent. Rayon-

NOV. 1ST 1927
TO
FEB. 1ST 1928

FEB. 1ST
TO
MAY 1ST 1928.

RELATIVE VALUE OF SALES.

Rayon

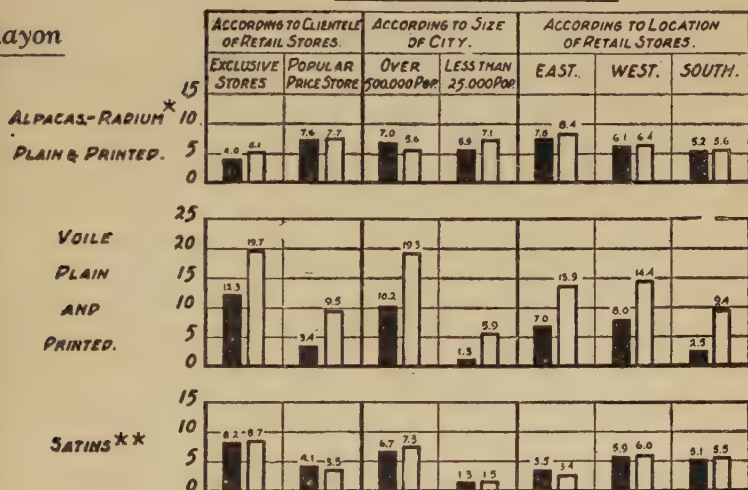


CHART 17. Comparison of the Relative Value of Sales of Raw Fabrics. Showing the Percentage that each Bears to the Total Sales in Wash Goods Department. Reports from "Wash Goods" Department of 95 Retail Stores in 42 Cities in 21 States.

containing fabrics take the dominant position in the sales of bedspreads. Tablecloths, towels, bedsheets, tickings and blankets, are all now being made with Rayon. In all these fields this fiber has good possibilities, as it enhances the attractiveness without materially increasing the cost.

* Rayon and cotton mixtures.

** Rayon mixed with silk or cotton.

CONSUMPTION OF RAYON IN THE WOOL INDUSTRY

The U. S. census of 1925 shows that 2,500,000 pounds of Rayon were consumed by the woolen industry. Two hundred and sixty-three million pounds of cloth, however, were produced during the same year by that industry. With the growing demand for lightweight woolen dress fabrics, most successful cloths have been originated in Europe in which Rayon was combined with wool, to give lightness and richness. Similar fabrics when made in this country met with good response. It is possible that the consumption of Rayon in woollens for women's wear will show a more rapid growth than it has as a decorative medium for men's wear.

CONSUMPTION OF THE UNDERWEAR INDUSTRY

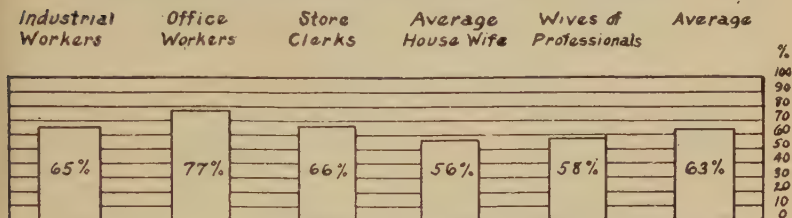
The consumption of Rayon by the knit underwear industry has shown a very remarkable growth. From 4,000,000 pounds in 1924 it jumped to 7,000,000 pounds in 1925 and to 29,000,000 pounds in 1927. To ascertain whether this increase was permanent, as well as to find out whether there were any conditions which should be remedied, the Viscose Company and the Du Pont Rayon Company made a very extensive study in 1926 in cooperation with the National Retail Dry Goods Association. Several thousand women and more than five hundred retail stores supplied the information which was tabulated in the form of charts, a few of which are shown on the following pages.

It was found, as shown on Chart 18, that on the average 63 per cent of a representative group of women have used Rayon underwear in 1926 and that 84 per cent of them were well satisfied with it. One out of every four women liked Rayon underwear because it wears well, and one out of every

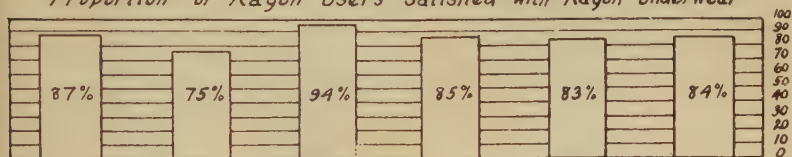
five on account of its softness; 16 per cent of the consumers were keen about its appearance and color, while 10 per cent praised its comfortableness and the ease with which it can be washed.

Information Secured From 2,000 Consumers

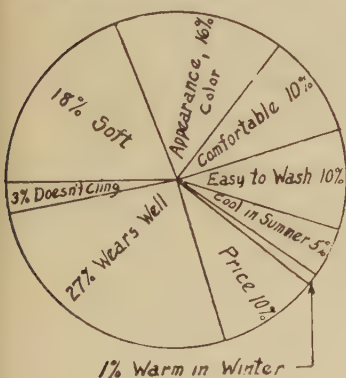
Proportion of Consumers who use Rayon Underwear



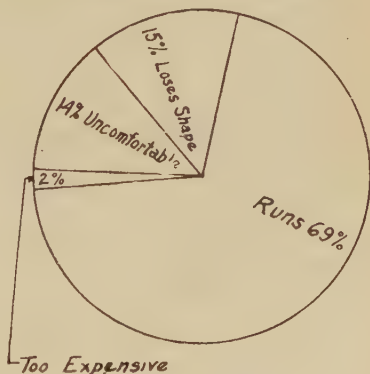
Proportion of Rayon Users satisfied with Rayon Underwear



Why Were Consumers Satisfied with Rayon Underwear?



Why Were Consumers Dissatisfied with Rayon Underwear?



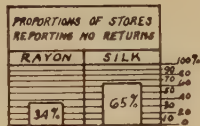
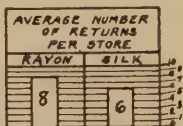
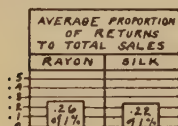
February 1, 1927

CHART 18. Women's Rayon Underwear.

The fact that women's Rayon underwear was entirely satisfactory from the consumer's standpoint was also substantiated

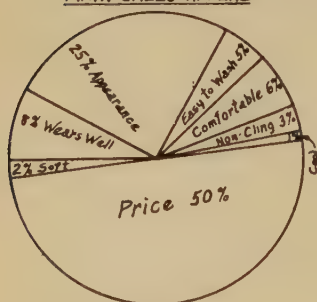
Information from 450 Store Buyers

Returns due to complaints During a period of Three Months

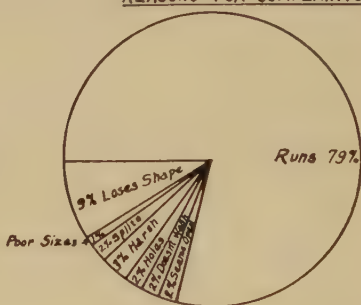


RAYON UNDERWEAR

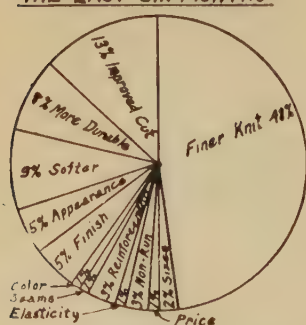
MAIN SALES APPEAL



REASONS FOR COMPLAINTS



IMPROVEMENTS NOTICED IN THE LAST SIX MONTHS



IMPROVEMENTS WHICH WILL
INCREASE THE SALEABILITY



CHART 19. Women's Knit and Woven Underwear.

by the small percentage of this merchandise which was returned to retail stores on account of complaints, as indicated

on Chart 19. We are quoting comments on this chart made by Mr. Sommaripa in a report prepared by him in 1927:

The problem of returns in the Underwear Departments of retail stores is not as serious as it is in other departments. The returns of silk underwear average only about $\frac{1}{5}$ of 1%, while in rayon they amount to $\frac{1}{4}$ of 1%. This compares very favorably with the returns for some other textiles handled by retail stores which are said to run often considerably above 1%.

Complaints about knitted rayon underwear usually are that a "run" has appeared. This can be due either to the fact that the garment was defective as a result of poor yarn, or poor knitting, or because the consumer did not care for the garment properly.

The other complaint of some consequence is that "Rayon loses its shape." This occurred because the cloth of the garments was unduly stretched in manufacturing. This defect, however, has been eliminated to a great degree by improvements which have been made in the quality of rayon underwear.

The great majority of retailers stated that these difficulties have been overcome to a great extent by improvements in the quality of rayon underwear during the last six months of 1926 as well as because the consumers have learned to treat rayon in the same way as silk, which insures good wearing. A number of retailers, however, believe that rayon underwear made absolutely run-proof would be a large seller, even at much higher prices. To be run-proof Rayon has to be knitted on machines similar to those on which glove silk is manufactured.

Ninety-two per cent of retail store buyers from whom information was secured, have definitely stated that during the last six months of 1926 the quality of Rayon underwear was greatly improved. This was partly due to the greater experience acquired in the manufacturing of Rayon underwear, and also because the prices of Rayon yarn have been considerably reduced, thus allowing manufacturers to give much better qualities of finished goods without increasing prices.

One of the improvements about which comments were

made by almost half of the store buyers interviewed was that Rayon underwear was knitted finer than in the past. The compactness of knitting to a great extent prevents the development of "runs."

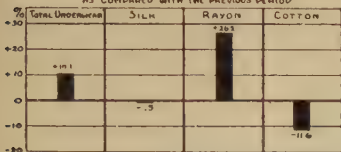
Distinct improvements were noticed in the cut and finish of the garments, in the range of sizes, and durability. Almost 10% of the comments of store buyers stated that Rayon underwear is being made much softer. This may be the result of improvements in the yarn or in the finishing of the garments.

About one-third of the retailers thought that it is desirable to make Rayon underwear absolutely run-proof. This can be accomplished by knitting it on the same kind of machine as glove silk or milanese. Several retailers thought that Rayon underwear thus manufactured will be a large seller, even at prices 50% (or more) higher than the ordinary kind.

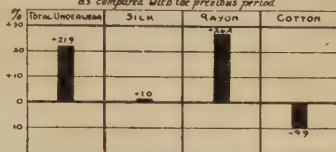
The other important improvements seem to be more in the direction of better manufacturing of finished articles. They touch on such questions as reinforcements, better shoulder straps, seams, and a greater range of sizes. Only 6% of the store buyers desired an improvement in the laundering qualities of Rayon. This indicates that the question of proper laundering of Rayon is not any longer of great importance. Only 2% of the complaints, indeed, were due to laundering troubles.

Having ascertained that Rayon underwear was entirely sound merchandise acceptable to the customers, it was of interest to find out its relative importance and its probable potential growth. It is shown that on the average women consume about 19 items of underwear per year, of which in 1926 only about 3 items were made of Rayon. The consumers of the higher classes used it even to a greater extent which proved that it was of proper quality. Girls working in factories were another group who used more Rayon underwear than the average housewives, thus indicating that Rayon underwear is suitable for the strain which undergarments,

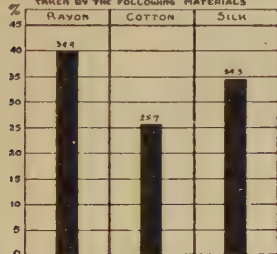
% of Increase or Decrease in Sales in DOLLARS during this period as compared with the previous period



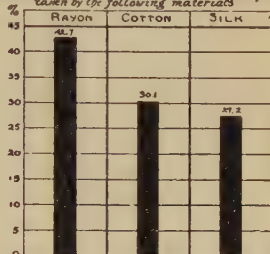
% of Increase or Decrease in Sales in DOLLAR PARTS during this period as compared with the previous period



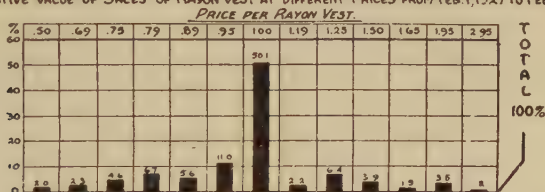
Relative Value of Sales of Undergarments in DOLLARS taken by the following materials



Relative Volume of Sales of Undergarments in DOLLAR PARTS taken by the following materials



COMPARATIVE VALUE OF SALES OF RAYON VEST AT DIFFERENT PRICES FROM FEB. 1, 1927 TO FEB. 1, 1928.



RELATIVE IMPORTANCE OF VARIOUS ITEMS OF UNDERWEAR BY DIFFERENT MATERIALS SOLD IN RETAIL STORES.

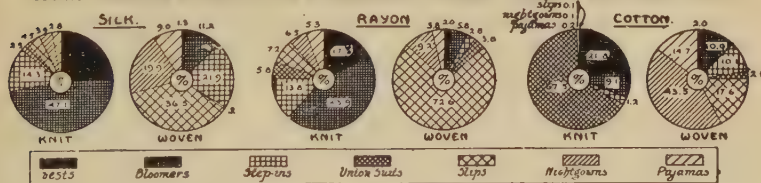


CHART 20. Women's underwear, Relative Value of Sales of Silk, Rayon and Cotton, February 1, 1927, to February 1, 1928, taken as the base.

worn by people engaged in manual occupation, have to undergo. The consensus of opinions, secured from retail stores buyers, was that Rayon underwear of average price has better wearing quality than low-priced silk. They also thought that Rayon underwear has style and color appeal equal to silk.

In 1927 as against 1926, the value of sales of Rayon underwear at retail increased 45 per cent while those of silk decreased 5 per cent and cotton underwear declined 11.6 per cent.

It is of interest that the relative value of Rayon underwear in proportion to the total underwear sales was about the same in large cities as in the cities with populations less than 25,000, and that the exclusive stores were handling Rayon in a big way. This emphasized again the fact that Rayon underwear had a broad appeal to the women in this country.

In 1928 as compared with 1927 Rayon underwear scored an increase again while cotton declined. The relative value of Rayon amounted in 1928 to 40 per cent of the total underwear business in dollars, and to about 43 per cent of the number of items. The prices were maintained at the level which made it possible to sell quality merchandise. The prices of the vest, for instance, were centered at around \$1.00—with only 5 per cent being done at less than 75 cents, the latter being somewhat of a danger point.

The knitted Rayon underwear took 56 per cent of the total value of sales of bloomers, 47 per cent of vests, 32 per cent of step-ins, and 25 per cent of pajamas, which is shown on Chart 21. The Rayon woven underwear, however, is more important than the knitted variety in the sales of slips where the former takes 29 per cent. In union suits the knitted cotton takes three-fourths of the business while in the sales of night gowns almost 80 per cent are taken by woven silks and cottons. It is clear, therefore, that in these two items of underwear Rayon still has large potential fields.

The census of 1925 shows that in that year more than 150,000,000 pounds of cotton were consumed in women's, children's and men's knitted underwear considered as a group. The above-mentioned figures indicate the decline in the consumption of cotton knitted underwear for women, and an

increase in Rayon. In 1928 an important increase was also shown in the sales of men's Rayon underwear. A study

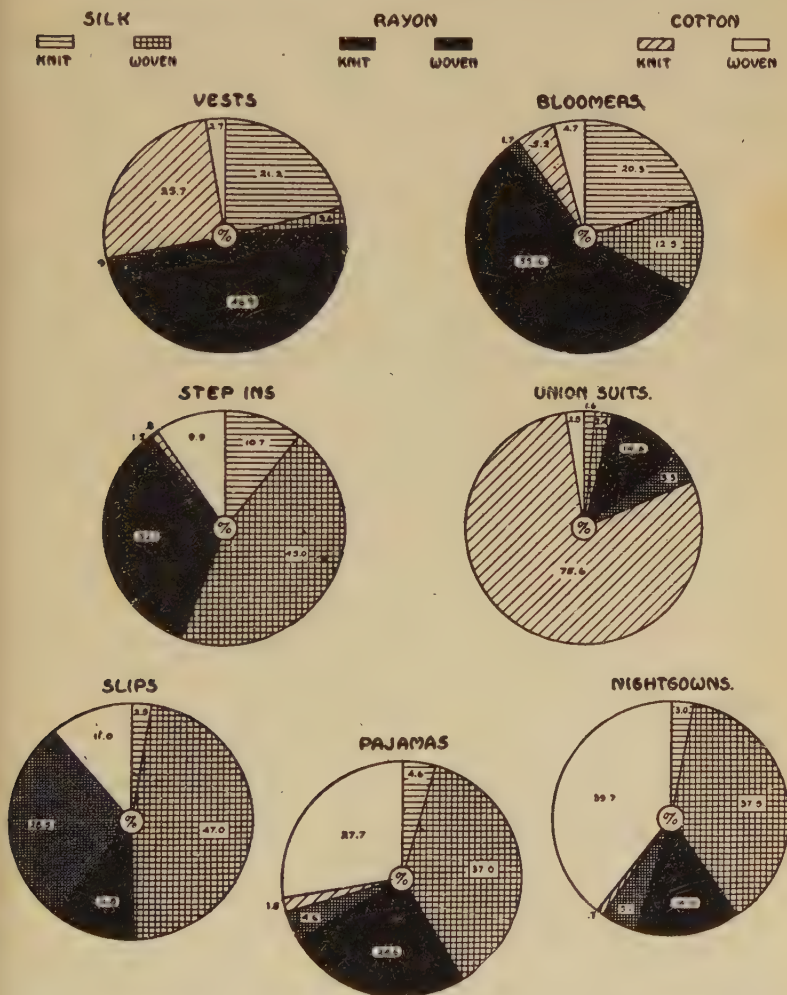


CHART 21. Women's Wear. Subdivision by Different Materials of Retail Sales of Various Items from Feb. 1, 1927 to Feb. 1, 1928. Report from 90 "Knit" and Underwear Departments combined with 43 Reports from "Muslin" Underwear Departments in 66 Cities in 31 States.

among retail stores indicated an increase of 27 per cent in the latter which took 12 per cent of the total underwear sales. Children's Rayon underwear is also rapidly gaining ground. It is reasonable, therefore, to assume that in years to come Rayon will secure a larger and larger proportion of the total knit underwear business.

CONSUMPTION OF RAYON BY THE HOSIERY INDUSTRY

The census of manufactures of 1925, shows the interesting fact that in that year cotton accounted for approximately 116,000,000 pounds of the materials consumed, while 12,000,000 pounds of silk and 10,000,000 pounds of Rayon were used by the hosiery industry. Almost half of the total number of dozens of pairs of hosiery were made entirely of cotton. It is very likely that roughly 50,000,000 pounds of cotton were used for the heel and toe in men's, women's and children's hosiery and in the top of women's hose. Such use of cotton yarn will probably be maintained. On the other hand, the consumption of cotton in the leg itself is steadily declining while the consumption of Rayon and silk is increasing.

The trends in production of hosiery can be observed from Table 48 where a comparison is made between 1923, 1925 and 1927. Tables 49, 50 and 51 show a more detailed classification of types of hosiery for a 12-months period from July 1st, 1926 to June 30th, 1927, and a similar period in 1927 and 1928. These figures are compiled from monthly reports issued by the Department of Commerce which cover approximately 60 per cent of the hosiery industry.

The total production of men's hosiery from 1923 to 1927 showed a steady increase. Cotton hosiery on the other hand declined during that period by more than one-fifth. Rayon hosiery increased more than 100 per cent while a decline of 50 per cent was shown by silk. From July, 1926, to June,

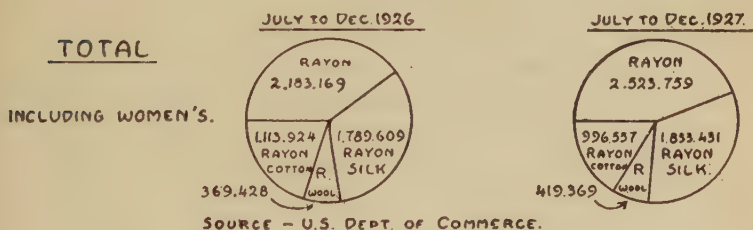
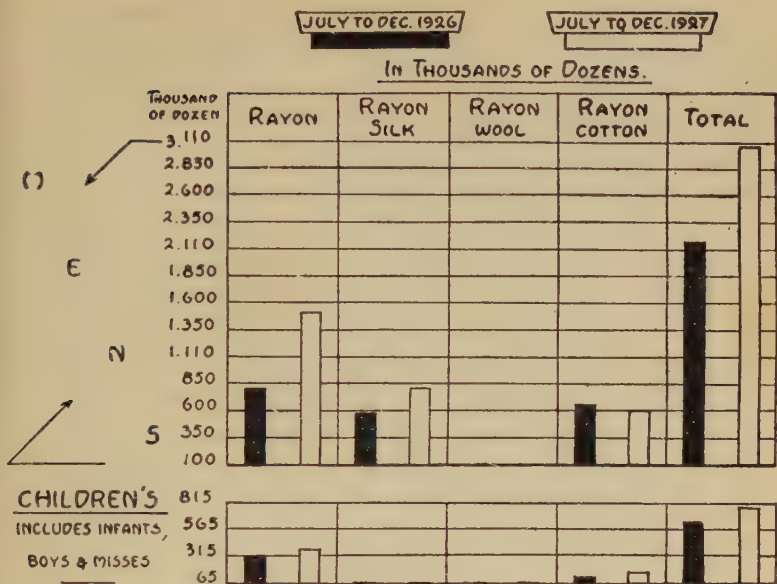


CHART 22.—Rayon Hosiery Production in the United States.

1927, as compared to the corresponding period from July, 1927, to June, 1928, men's hosiery made of Rayon in combination with cotton increased 41 per cent, Rayon and silk increased 62 per cent, while the cotton as well as silk hosiery showed a considerable drop. Of the total men's hosiery shown as having been produced in the above-mentioned reports for the latter twelve-months period, the Rayon containing hosiery accounted for about one-third. It is generally considered that

with the steady trend towards more attractive and better style merchandise Rayon containing men's hosiery will continue to show a growth.

The children's cotton hosiery declined 34 per cent in 1927 as compared to 1923. Rayon hosiery for children, on the other hand, increased 87 per cent from 1923 to 1925 and 51 per cent from 1925 to 1927. When a twelve-months period from July, 1927, to June, 1928, is compared with a similar previous period a 28 per cent gain is to be noted in Rayon and wool, a 106 per cent gain in Rayon and silk and 88 per cent gain in all Rayon children's hosiery. Of the total of 10,381,000 dozens of children's hosiery reported Rayon containing items accounted for about 28.5 per cent. Rayon adds considerable beauty to children's and infants' hosiery. It is not materially increasing the price of this merchandise. The retail stores and the mail-order houses report a steady increase in this business which bids well for its future. A radical change has been taking place in women's hosiery. The full-fashioned hose made of silk has been supplanting the seamless hose of cotton, Rayon or combination of Rayon and silk. From July 1, 1926, to June 30, 1927, as compared with a similar later twelve-months period the reported production of seamless hosiery declined from about 11,000,000 dozens of pairs to about 9,000,000. The full-fashioned hosiery, on the contrary, increased from 13,800,000 dozens of pairs.

During a twelve-months period beginning with July, 1927, the seamless hosiery made of Rayon, or Rayon mixtures, shows a drop in accordance with the general downward trend of that type of hosiery. In the field of full-fashioned hosiery, on the other hand, stockings made entirely of Rayon, or of Rayon and silk, have shown considerable gain. There was previously an objection to Rayon hosiery, namely that it had metallic sheen which made it apparent that a woman was wearing the cheaper hose. Table 48, however, shows that even the fac-

TABLE 48.—TREND OF HOSIERY PRODUCTION AND PER CENT OF CHANGE FROM 1923 TO 1925 AND 1925 TO 1927, THOUSANDS OF DOZEN PAIRS

	1923	1925	1927	Gain or Loss,	
				1923 to 1925	1925 to 1927
Rayon					
Men's.....	1,493	1,859	3,281	25.0	77.0
Women's Full-Fashioned.....	10	17	37	70.0	117.0
Women's Seamless (including Sports and Athletics).....	3,099	3,585	1,526	16.0	-47.0
Children's (including Infants', Boys' and Misses').....	432	809	1,226	87.0	51.0
Total.....	5,034	6,270	6,070	24.0	-3.0
Silk Mixtures (Including Rayon)					
Men's.....	1,036	2,143	2,407	107.0	12.0
Women's Full-Fashioned.....	236	98	176	-48.0	80.0
Women's Seamless (including Sports and Athletics).....	1,549	2,536	2,428	64.0	-4.0
Children's (including Infants', Boys' and Misses').....	184	385	336	109.0	-13.0
Total.....	3,005	5,162	5,347	72.0	4.0
Silk					
Men's.....	3,081	2,775	1,648	-10.0	-42.0
Women's Full-Fashioned.....	5,210	9,240	14,503	77.0	57.0
Women's Seamless (including Sports and Athletics).....	2,516	3,117	2,360	24.0	-24.0
Children's (including Infants', Boys' and Misses').....	135	197	248	46.0	26.0
Total.....	10,942	15,329	18,759	40.0	22.0
Cotton					
Men's.....	11,947	10,649	9,446	-11.0	-11.0
Women's Full-Fashioned.....	495	183	78	-63.0	-57.0
Women's Seamless (including Sports and Athletics).....	6,491	5,330	3,718	-18.0	-31.0
Children's (including Infants', Boys' and Misses').....	9,224	9,264	6,151	0.1	-34.0
Total.....	28,157	25,426	19,393	-10.0	-24.0
Total					
Men's.....	20,057	20,435	21,078	2.0	3.0
Women's Full-Fashioned.....	7,074	9,677	14,908	37.0	54.0
Women's Seamless (including Sports and Athletics).....	14,529	15,522	10,857	7.0	-30.0
Children's (including Infants', Boys' and Misses').....	10,632	11,334	8,980	7.0	-21.0
Total.....	52,292	56,968	55,823	9.0	-2.0

Source of information: Department of Commerce.

THE RAYON INDUSTRY

TABLE 49.—MEN'S HOSIERY PRODUCTION IN U. S., DOZEN PAIR

	July 1, 1926 to June 30, 1927, Inclusive (12 Mo.)	July 1, 1927 to June 30, 1928, Inclusive (12 Mo.)	Per Cent of Gain, Fiscal Year, 1928 Over 1927
All cotton.....	9,265,920	8,876,052	— 4.2
Wool and merino...	2,023,146	2,316,631	+ 14.5
Silk.....	1,826,128	1,553,173	— 15.4
Rayon.....	2,536,397	2,810,500	+ 20.5
Silk and wool.....	506,438	481,287	— 4.9
Rayon and wool....	234,948	216,332	— 7.9
Rayon and cotton..	1,229,679	1,733,196	+ 40.9
Rayon and silk.....	1,362,845	1,222,006	+ 62.0
All others.....	349,433	764,204	+118.9
Total.....	19,334,934	21,003,391	+ 8.6

Source of data: Dept. of Commerce. Above data represent approximately 60 per cent of total hosiery production in U. S.

TABLE 50.—BOYS' AND MISSES', INFANTS' AND CHILDREN'S HOSIERY PRODUCTION IN U. S., DOZEN PAIRS

	July 1, 1926 to June 30, 1927, Inclusive (12 Mo.)	July 1, 1927 to June 30, 1928, Inclusive (12 Mo.)	Per Cent of Gain, Fiscal Year 1928 Over 1927
All cotton.....	5,679,428	6,699,917	+ 17.9
Wool and merino...	324,552	320,726	— 1.1
Silk.....	255,166	305,792	+ 19.8
Rayon.....	868,464	1,622,047	+ 87.9
Silk and wool.....	125,895	109,035	— 13.3
Rayon and wool....	118,211	151,850	+ 28.4
Rayon and cotton..	438,235	901,598	+105.7
Rayon and silk.....	173,956	179,458	+ 3.1
All others.....	34,192	88,637	+159.2
Total.....	8,018,099	10,381,263	+ 29.4

Source of data: Dept. of Commerce. Above data represent approximately 60 per cent of total hosiery production in U. S.

TABLE 51.—WOMEN'S HOSIERY PRODUCTION IN U. S., DOZEN PAIRS

Seamless

	July 1, 1926 to June 30, 1927, Inclusive (12 Mo.)	July 1, 1927 to June 30, 1928, Inclusive (12 Mo.)	Per Cent of Gain, Fiscal Year 1928 Over 1927
All cotton.....	3,174,886	2,804,359	— 11.0
Wool and merino...	149,963	134,874	— 10.0
Silk.....	2,477,624	2,307,187	— 6.8
Rayon.....	1,863,347	1,043,067	— 44.0
Silk and wool.....	352,085	257,509	— 26.8
Rayon and wool....	290,809	304,537	+ 4.7
Rayon and cotton..	281,451	181,069	— 35.6
Rayon and silk.....	2,397,593	1,938,126	— 19.1
All others.....	9,998	50,495	+405.5
Total.....	10,997,756	8,821,223	— 19.7

Full-Fashioned

All cotton.....	142,684	43,245	— 69.6
Wool and merino...	26,376	7,526	— 71.4
Silk.....	13,346,022	15,771,087	+ 18.1
Rayon.....	18,116	210,923	+1208.7
Silk and wool.....	48,343	56,974	+ 17.8
Rayon and wool....	38,659	30,757	— 20.4
Rayon and cotton..	86,958	16,858	— 80.6
Rayon and silk.....	48,331	203,033	+320.0
All others.....	15,117	15,117	— 5.1
Total.....	13,771,439	16,362,853	+ 18.8

Source of data: Dept. of Commerce. Above data represent approximately 60 per cent of total hosiery production in U. S.

tory workers and the wives of laborers were buying, on an average, hosiery at prices which indicate that they were using silk. The per capita consumption of Rayon by women of different classes gives some clue to the hosiery consumption in this country. See Table 52.

SUMMARY OF CONSUMPTION OF RAYON

We have discussed the consumption of Rayon by the silk, cotton, woolen knit underwear and the hosiery industries, which together accounted for about 88 per cent of the consumption of Rayon. We have shown that the increase in the uses of Rayon by the silk industry depends upon the development of high novelties where Rayon is used on account of its special effects and particularly upon the launching of staple fabrics where Rayon comes in direct competition with weighted silks. The increase in consumption of Rayon by the cotton industry depends upon its uses in washable women's and children's wearing apparel. In knit goods the greatest field seems to be in men's underwear. Men, however, are not as yet well familiar with this merchandise. It can thus be deduced that the consumption of Rayon during the next few years will be determined by the amount of effort in creating the prestige and confidence for it among women and familiarity with it among men. With the rapidly growing production, it may be necessary to work harder to secure additional outlets. The development of new uses and maintenance of the standards of qualities in existing Rayon containing merchandise are also assuming greater importance. All of this brings us to the subject of merchandising and advertising of Rayon.

MERCHANDISING OF RAYON

As explained before, the supply of Rayon during the last few years has been about equal to the demand for it. Such conditions could almost have induced Rayon manufacturers to confine their sales efforts to opening and closing of their books. There were many pioneering problems, however, connected with the use of Rayon by textile mills. In order to assist them, the Rayon yarn manufacturers maintained active sales departments, composed of textile men. Through the

close contact with the mills, not only the best ways of processing Rayon have been developed, but also considerable information as to the desirable improvements to be made in Rayon were secured. It was, therefore, through the knowledge of the needs of the textile industries that such developments as the multi-filament Rayon or low-lustre type of yarn were made. Rayon yarn manufacturers are doing some advertising to the trade to get the mills and users of fabrics acquainted with their individual products. Besides, a general educational campaign for Rayon has been conducted by the Rayon Institute, a joint organization of the leading Rayon manufacturers. We will discuss in detail the merchandising of Rayon yarn, the channels of distribution of fabrics, and the advertising and promotional activities on behalf of Rayon.

An important part of the total production of Rayon in this country now leaves the plant of the Rayon producer in packages which can be used immediately on the knitting machine, in the shuttle as filling, or in the warping mill to make warps for the loom. A great amount of Rayon, however, still goes in the form of skeins. The latter in some instances must be dyed or twisted with the voile or crêpe twist. In such cases the skeins often go to the so-called converter of yarn who either buys and sells the yarn outright or performs the operations on a commission basis. The same is true of Rayon which has to be doubled with other yarn or made with fancy effects. There are also many mills which do not have winding equipment of their own and have to have an outside throwster put it on cops or cones for them. In all these cases the yarn goes to the mill from the Rayon producer via the dyer, converter or throwster.

Most domestic Rayon is sold by the producers directly to the mills though some of it is sold to the converters and in some cases to the jobbers, who later re-sell it to the mill. The Rayon manufacturers usually have salesmen, who are to a great extent technical men well familiar with the process-

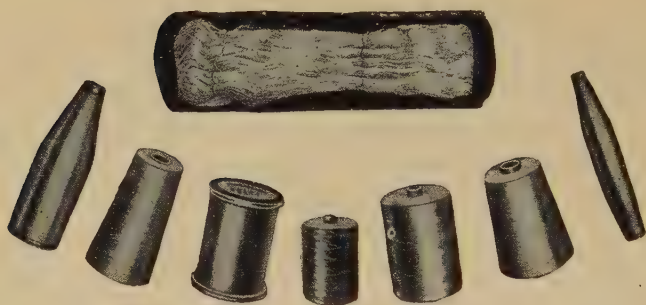


FIG. 34. Skein, Tubes, Cones and Spools.

ing of Rayon in textile mills. It is usual for the salesmen to discuss with the customers their technical problems of handling Rayon. In most instances, however, the territories are allotted to salesmen geographically, which usually means that they have a great variety of industries in their territories, many of which present different problems. To cooperate with the customers most efficiently in developing the best methods of handling Rayon, it is customary for Rayon manufacturers to have technical experts who specialize in knitting, weaving, sizing or dyeing of Rayon, and who can spend several days or weeks at the customer's plant working out a problem. With the continuous development of better grades of Rayon fabrics

TABLE 52.—WOMEN'S HOSIERY

Per Capita Consumption of Hosiery by Different Classes

Wives of Laborers	Middle Class Housewives	Store Clerks	Industrial	Wives of Doctors and Lawyers	Office Workers
8.4	10.8	11.2	18.8	14.5	19.2
<i>Average Price Paid per Pair</i>					
\$1.208	\$1.618	\$1.78	\$1.367	\$2.015	\$1.766

Source of data: Personal interview with 1500 women.

a closer adaptation of the equipment is required. The differences in humidity, type of help, machinery, kind of water used, etc., vary the conditions to such an extent that a problem in each plant has to be worked out separately and no rule of thumb is possible.

As mentioned before, a certain part of Rayon is dyed in the yarn. Rayon is also used as in the case of Rayon and cotton bedspreads, etc., in the white, while the other yarns may have been dyed previously. Most of the gingham mills and many of the plants producing bedspreads, damask, ingrain hosiery, have their own dye-plants.

The major part of Rayon yarn as in the case of voiles, satins, crepes, underwear tubing, and women's hosiery, is knitted or woven and then dyed and finished. Some of the knitters have their own dye-plants while most of the silk mills and cotton mills do not have piece-dyeing or printing equipments.

The bulk of Rayon fabrics woven by cotton mills is sold by them in the gray through brokers to converters. The latter decide how the goods are to be styled and send them to a finisher who dyes, prints and in some cases, bleaches them. An important number of silk mills, however, style the goods themselves and have them finished for their own account. After the woven fabrics have been styled and finished they are sold either directly to manufacturers of dresses, underwear, etc., as well as to retail stores, or they are purchased by wholesalers who in turn sell them to manufacturers and retailers.

Hosiery is often sold by manufacturers directly to retail stores, but an important proportion of it reaches the latter through wholesalers.

There are many plants of knitters who make Rayon underwear out of cloth which they produce. In some cases they sell to wholesalers, chain stores and mail-order houses while

in other instances they maintain large sales' organizations which not only reach department stores but also specialty shops and small town dry goods stores. When this occurs the products are usually nationally advertised. There are other knitters of Rayon fabrics who sell their cloths to manufacturers who cut it into underwear. The underwear manufacturers in turn dispose of it directly to retail stores or sell it to jobbers.

It is customary in England for Rayon manufacturers to have weaving plants of their own which utilize only a small part of the yarn output. In this country, one of the Rayon producing companies installed knitting and weaving machinery primarily to produce new cloths which could be set as a standard to be followed by their customers. Later, the operation of most of this equipment was discontinued, the Rayon producer finding it more advantageous to have fabrics woven on commission. An arrangement was made with a commission house to sell these fabrics under the branded name of the yarn. These fabrics were used as the opening wedge to get retailers and dress manufacturers acquainted with the fabrics of better construction made from this yarn. In a way the yarn manufacturer was competing with his own customers but this arrangement was generally considered beneficial as it enabled the retailer or the cutter-up to gain his first experience through the use of a high-grade article. As long as the same trade name was used to designate the finished cloth and the yarn, it was hard at a later date to discriminate between standard high-grade cloth and low-end fabrics made from the same yarn. The yarn manufacturer, therefore, announced that it would pay a bonus per yard of cloth produced of its yarn which was made in certain high count constructions.

We have explained the above arrangement in detail in order to make it clear how complicated it is for the retailer and the consumer to judge the different grades of Rayon

fabrics. To start with, not only Rayon yarn of different weight produces different results, but also the same manufacturers sell various grades of the same weight yarn, the price differential being at times as high as 30 per cent. Moreover, the yarns of certain domestic manufacturers have the reputation of being better than others. Good Rayon, however, can be willfully made into a very cheap article, or it may be spoiled in the manufacturing processes. Unless a branded name is attached to a fabric to be sold by the yard, thus placing the responsibility on the cloth manufacturer or converter for the selection of the yarn, the construction of the fabric and the skill in weaving and finishing it, the retailer or the dress manufacturer is in a hard position in selecting the fabrics. When dress or underwear is sold ready made, the situation is even more complicated as the making of the finished garment has a great deal to do with its serviceability.

Besides the reliance on a branded name or the reputation of a given manufacturer the retailer has now, and the consumer will have in the future, recourse to an impartial testing laboratory. It is easier at present for a retail store buyer to demonstrate his efficiency by the fact that he is selling his merchandise at lower prices than his competitor than to prove his knowledge in selecting better values for the price. Now the buyer when selecting fabrics can send samples to be analyzed by experts and secure a report which will show him which merchandise is the better buy. The consumer, in the future, if dissatisfied with the wearing quality of an article will be able to send it to a laboratory which will place the responsibility as the case may be on the laundry, dry cleaner or the retailer. The latter in turn will trace it to the garment or the fabric manufacturer.

The problem described before probably explains the reasons why with all resources at their command, and in some cases with a great investment in institutional advertising, the

Rayon yarn manufacturers have not advertised extensively their branded names to the consumer.

ADVERTISING

The Rayon which was put on the market some five or ten years ago was far inferior to what it is now. The fabric manufacturers have also since developed methods of handling Rayon which insure the quality of the finished article. The misnomer "artificial silk" carried connotations which, in a way, were derogatory to the product. The word Rayon was wisely adopted to take the place of the term "artificial silk." In so doing the yarn manufacturers, the retailers and the government indicated that a new important textile was in existence which could stand or fall on its own merit. Previously to that, large quantities of Rayon were sold to consumers under misleading terms, such as "Art Silk." With the adoption of the word "Rayon" the attention of consumers was focused on it in 1925-26 by retail store advertising. As is usually the case with any class of merchandise there is more goods sold at popular prices than there is of exclusive high-grade merchandise. With the great variety of finished products containing Rayon it is only natural that it took the retail stores some time to learn which of their articles were partly or totally made of Rayon. The result was that the consumer became acquainted with Rayon through the lower end merchandise as a comparatively small number of high price Rayon items sold in those years were almost unnoticed by the retailers and consumers. In 1925-26, moreover, there were still some articles sold, made previously, which were not satisfactory. Some of the consumers thought that Rayon was a branded name and, having unsatisfactory experience with the cheaper merchandise, assumed that everything carrying the name Rayon was not of high quality. Although the sales of

Rayon were rapidly growing, a misunderstanding of what it was and a prejudice against it began to grow.

Realizing this, the Rayon producers decided to ascertain whether the general run of Rayon merchandise was satisfactory. In doing so, it was important to know what types of consumers were buying Rayon articles of different varieties and at what prices. Extensive studies of women's hosiery, underwear and of piece goods and draperies were made among retailers and consumers. It was found that in 1926 women's hosiery made with Rayon was considered to give excellent wearing service but that it was usually of the seamless variety and that the latter was criticized for not holding its shape. Only women of very limited means were using Rayon hosiery. This, of course, does not apply to sport hosiery. Only a small proportion of the hosiery sales of department stores was of Rayon. The latter was also criticized for being too shiny. Women's Rayon underwear, on the contrary, was handled in a large way even by most exclusive stores. It was considered as possessing the same style appeal as silk and was selling to women of all classes to their entire satisfaction. In bedspreads, upholstery and draperies, Rayon was the standard merchandise, considered by many retailers as being superior in sheen, body and wearing quality to silk. In the wash-goods departments criticisms of coarse Rayon alpacas were voiced, which, however, were silenced with the appearance of the high-grade Rayon and cotton radiums and the all Rayon voiles. In the silk departments in most instances Rayon transparent velvets and the Rayon and wool mixtures were sold as silk as late as 1927. The same situation was true in the ready-to-wear and negligee sales. The author in many instances had buyers tell him that they had no luck with Rayon and almost in the same breath praised the attractiveness, wearing qualities and rapid sales of merchandise which, to their surprise, proved to be Rayon. A study made

among customers of a large mail-order house indicated that half of a representative group of them did not know at all what Rayon was.

After careful consideration, a decision was reached by some of the leading producers of Rayon yarn that a joint educational campaign was desirable. It was thought necessary to draw the attention of the consumers and retailers to the use of Rayon in a high-grade merchandise in order to establish the fact that Rayon, like any other textile, is to be found in a whole range of articles, from the most expensive to the cheapest. The campaign was not intended to increase the sales of Rayon yarn but to build prestige for the industry for the years to come. The yarn producers were oversold in 1927, but the executives of the leading companies believed that the eventual maximum growth of the industry depended upon building up of good will for it. This could be accomplished by simply showing to the consumers the high-grade materials which they did not know were made of Rayon and by educating the stores to capitalize the fact that it was the characteristics of Rayon which made possible the creation of these high-grade materials.

An initial appropriation of \$500,000 was made by the Viscose Company, DuPont Rayon Company, Industrial Rayon Corp. The Belamose Corporation and the Am. Glanzstoff Corp., which together formed the Rayon Institute for cooperative advertising and promotion of work. The campaign was to be directed to the consumers and the retail trade. It was believed that the most effective way of obtaining recognition for Rayon was to show illustrations of it as used in women's apparel of highest quality made by the leaders in the French culture. Most of the famous dressmakers have been using Rayon in their creations for the last few years. It was not difficult, therefore, to buy most beautiful gowns containing Rayon at their seasons' openings. As shown in Fig. 35, which

is a specimen of the type of the consumer's advertisement used, the story was built around the testimony of a given well-known dressmaker. In most cases his or her picture and letter appeared together with a beautiful Rayon gown.

The consumption of Rayon in women's dresses was not as important as in underwear or in men's hosiery or interior

The loveliness of Rayon proclaimed by

DRECOLL



"I have found rayon well adapted to the subtle sophistication of the mode and consider it a priceless addition to the materials at the designer's command"



Rayon requires no laundering only the same precautions you would ordinarily take with our fine fabric

Send for "The Mode and Rayon," a book telling the story of rayon and its use by Parisian couturiers. Illustrated with rayon creations by Drecoll and other famous designers.
RAYON INSTITUTE, 150 Fifth Avenue,
New York, Dept. V-2.

Please forward my free copy of "The Mode and Rayon."

Name

Address

FIG. 35. Specimen of Consumer's Advertisement.

decoration. It was thought, however, that women are so much interested in dresses that this item would be a good attention-catching device. If a woman is satisfied that a certain material is good enough for dresses, she surely would be willing to use it in her underwear or to buy it in men's gift items. It was felt, moreover, that no single authority would carry as much

weight as a group of the world's fashion leaders, particularly when they are just stating facts.

Considerable space in each advertisement was devoted, by the Rayon Institute, to the description of other important other items in which Rayon was used. The media used and the approximate cost for six months are indicated by the following figures:

<i>Magazine</i>	<i>Insertions</i>	<i>Cost</i>
Vogue	6	\$ 19,200.00
Harper's Bazar	6	17,600.00
New York Times Rotogravure	2	9,221.44
Delineator	4	29,200.00
McCall's	4	40,000.00
Good Housekeeping	6	45,000.00
Ladies' Home Journal	6	75,000.00
Butterick Quarterly	2	12,000.00
McCall's Quarterly	2	7,500.00
Pictorial Review Quarterly	2	7,500.00
		\$262,221.44

Trade advertisement was used to inform the retail stores, the wholesalers and the dress manufacturers of the consumer's advertising and its purposes. It directed the attention of the trade to the campaign and to increased prestige which was expected to accrue to Rayon fabrics as a result of these efforts. The trade advertising was designed to induce retailers to sell Rayon as Rayon without apology and to lead them to regard the name "Rayon" as that of a material of high quality. Full-page and double-page space were used in Women's Wear Daily, Women's Wear Magazine, Men's Wear, National Retail Clothier, Dry Goods Economist and Dry Goods Merchant's Trade Journal. The space cost of this trade advertising was approximately \$25,000.

The principal promotional work of the Rayon Institute

was style shows, the object of which was to promote the prestige of Rayon by showing, in department stores or large specialty stores in important cities, beautiful merchandise containing Rayon. Live models were employed who wore the newest Rayon creations of French fabric designers and dress manufacturers. These gowns were used as the main feature. A considerable number of garments and fabrics, however, were selected from the stock of the store in which the exhibition was held. Various Rayon fabrics, such as draperies, bedspreads, table cloths, etc., were used as background and setting for the style show. Displays were also made of men's wear items as well as women's underwear. In this way the sale of actual Rayon merchandise was promoted in each store, thus obtaining its most whole-hearted cooperation in publicity and display work.

A booklet upon Rayon was prepared for dissemination of selling points for different types of Rayon merchandise.

A publicity department was created to supply the newspapers and magazines with information regarding Rayon. To accomplish this in the most effective way a person was employed to keep in touch with new fabrics containing Rayon, which were appearing on the market from time to time. Textile manufacturers who advertised to the trade, or nationally, were contacted by a representative of the Rayon Institute to explain in detail the purposes of the campaign and to point out the value to them of capitalizing in their own advertising the general education work done jointly by Rayon manufacturers.

The members of the Rayon Institute are at liberty to continue their own trade advertising. The latter usually consists of advertisements in magazines which reach textile mills. An interesting example is given in Fig. 36. This is the type which may be called "symbolic poster." It deserved an editorial in a national chemical medium which commented on

the fact that a large company was giving credit for the quality of its product to its chemical staff.



A CHEMICAL PRODUCT *by* MASTER CHEMISTS

DU PONT

RAYON

DUPONT RAYON

Reg. U. S. Pat. Office
DU PONT RAYON CO.
BUFFALO, N. Y.

Du Pont Chemical Control Assures du Pont Quality

FIG. 36. Specimen of Trade Advertisement.

A few companies, not members of the Rayon Institute, are doing some consumer advertising which is usually carried in fashion magazines such as *Vogue* or *Harper's Bazaar*.

PART C: INTERNATIONAL TRADE ECONOMICS

COMPARATIVE QUALITY: It is generally conceded that American-made Rayon is superior in quality to the average European product, although the European Tubize, Celanese, and Courtaulds output are recognized as on a par with American quality. A great deal of European Rayon brought to the American trade has been so bad that its use has, no doubt, been responsible for some of the unsatisfactory materials which have prejudiced a large part of the public against synthetic fibres. One of the chief defects of the foreign material is the variation in denierage in the same skein. This, of course, causes winding troubles, streaks, breaks under tension, etc.

Foreign skeins are put up in shorter lengths averaging $1/3$ to 1.2 of the American skeins. This means much more frequent stoppage in winding and the domestic Rayon consumer prefers the large, uniform, American-made skein. There is also a difference in the European and domestic method of winding; the European reel is straight wound and the domestic reel is cross wound. The straight reel produces many tangles, which sometimes make winding costs prohibitive. In view of the generally inferior quality of European Rayon yarns and the fact that they have no price advantage, it is evident that our imports are supplemental to meet an unfilled demand, for domestic weavers and knitters of Rayon are not likely to run the risk of jeopardizing the quality of their finished product by using an article of questionable grade.

Consuming industries in the United States and abroad

have widely differing needs and the requirements of the one do not fit those of the other. It should be the aim of the Rayon producer to meet the needs of his consumers as exactly as possible. This, the American producer is doing and he is spending time, money and effort to give his customer just what he wants. That Europe is capable of quality-production is evidenced by the fact that she has supplied us, and still does to an extent, with most of our fine sizes. American producers are rapidly getting into this class of production, but it is likely that Europe will hold her lead in the extremely fine sizes on account of her more favorable labor costs.

CLASSIFICATION OF FINISHED GOODS: There has not been a uniform classification of articles made up of Rayon yarn in the various producing countries so that it is impossible to compile tables of much value for comparison. Hosiery is one item which has had a fairly distinct classification and therefore statistics of some dependence may be obtained. The Bureau of Census of the United States is compiling such statistics.

COMPETITIVE CONDITIONS: Under this heading we must consider competitive conditions in the United States and Europe on the one hand as regards (1) Rayon yarn, and on the other hand as to (2) Rayon goods.

(1) In regard to Rayon yarn: Expansion in the last few years has made the United States the largest producer of Rayon in the world, and there is every indication that this lead will be maintained. The industry in the United States benefited at the start by European experience, and used the familiar methods there prevailing, but finally became independent of European influences. Even the Rayon producing machinery for the American industry is beginning to be manufactured in the United States. The American industry can claim full equality with the European in technical matters.

Europe has some advantages in having a more adequate

stable and experienced labor supply; wages are lower and there is less industrial unrest. Labor costs in the United States average about one-half of the total production cost. Therefore an efficient and trained labor force is important and so far the American Rayon industry has been forced to educate and train its own labor personnel. A factor of great advantage to the European producer is the ownership of patent rights controlling many phases of the various processes, a thing which is just beginning to be augmented in the United States. Many secrets of the trade are protected in Europe by patents, and the Rayon producers operating in this country are obliged to pay for the privilege of using them. Irrespective of longer experience, lower labor costs and the control of patent rights, European Rayon yarn producers are not serious competitors in the American market.

(2) Competitive conditions in regard to finished goods: Only in the millinery field does the United States have foreign competitions, and this mostly for the reason that it does not yet make the Rayon wool and Celophane and do the braiding and processing as cheaply as it can be done in Europe. With an increase in Tariff rates in 1922 this competition has weakened somewhat. From a standpoint of quality the hosiery manufacturers have no serious competitors. What goods of this class do come in are of lower grade—a market class the United States manufacturers do not cater to. The principal foreign competition is in exclusively designed fabrics of ultra-high grade and price, which go to a high-class trade, but the bulk of manufacture is high-grade staples still within popular price limits.

EUROPEAN PRICES: These do not always parallel American prices. In case of any readjustments in wholesale values our price-changes are reflected more quickly than those in Europe. For the last two or three years wholesale prices in Europe have been very close to the domestic price-level and

the addition of freight, duty and insurance brought the delivered price of the European article above domestic schedules. Even if the differential were in favor of the European product, the average quality of the European article is such that most domestic consumers would not be interested in its purchase. Recently Snia Viscosa offered some of its Polish product here at ten cents under the local market. This, however, is a quality product which is seeking a market.

IMPORTS AND EXPORTS: The imports and exports from one Rayon producing country to another can best be understood from the study of comparative tables and charts which are to follow herewith, beginning with the United States.

In the chapter on Rayon Production, Table 4 shows the approximate consumption, production and the imports. This table is illuminating as it shows a gradual increase from year to year, beginning with 1911 to end of 1928, of imports of Rayon yarn. In 1911 only 1,800,000 pounds were imported as against 12,746,718 pounds in 1927, and this notwithstanding the steady increase in production of Rayon in the United States, from 2,100,000 pounds in 1911 to 91,300,000 pounds in 1927. The total annual imports of Rayon yarn can again be studied from the following Table 53, which gives the imports by countries from the year 1924 to 1927. This table shows at a glance the countries which ship most of their Rayon yarn to this country, and indicates the tendency of countries which produce for their own use and those which are distinctly exporting countries.

Chart 23 gives, by months, the trends of imports to the United States from Italy, Germany, France and Netherlands for the years 1926, 1927 and 1928.

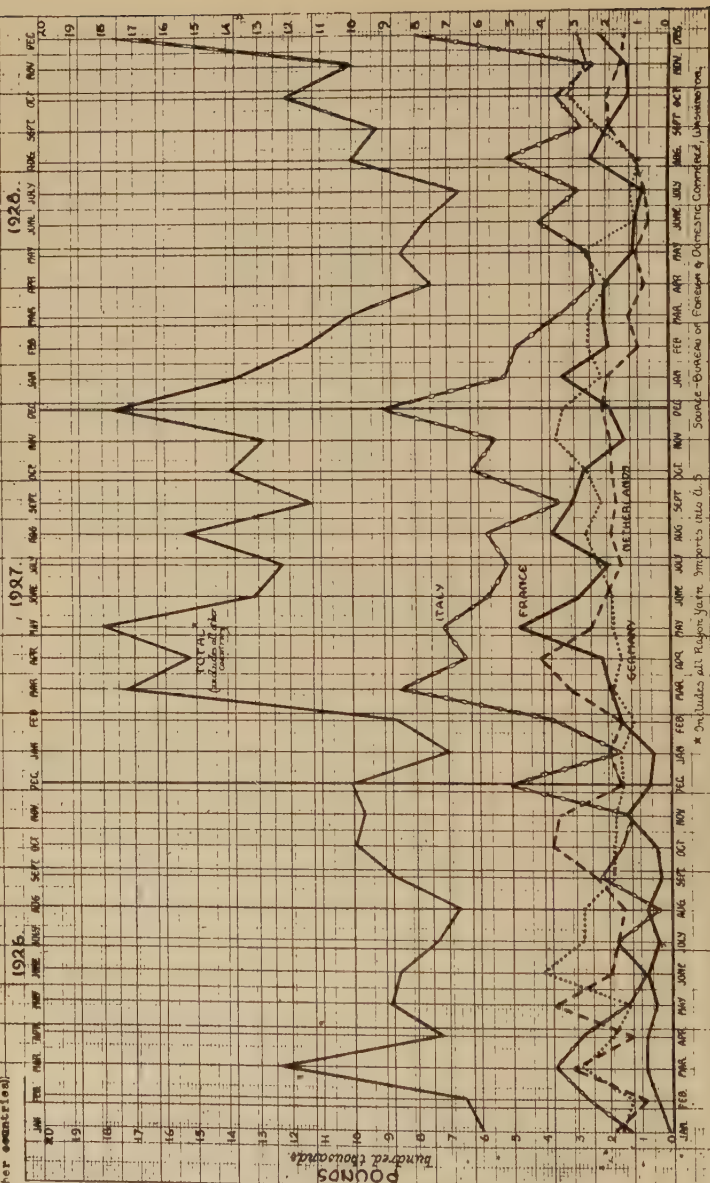
Chart 24 and Tables 53A and 53B, indicates that though the proportion of 150 and 300 denier Rayon still takes the bulk of importations the deniers finer than 100 are gaining in relative importance.

TABLE 53.—IMPORTS OF RAYON INTO THE U. S. BY COUNTRIES
FROM 1924 TO 1927

	1924		1925	
	Pounds	Dollars	Pounds	Dollars
Italy.....	107,573	115,549	2,261,965	2,155,868
Germany.....	231,279	350,734	1,515,016	1,931,288
France.....	13,376	30,121	298,344	340,972
Netherlands.....	577,551	645,139	1,033,682	1,093,791
Belgium.....	274,960	352,625	589,840	712,509
Austria.....	16,826	16,233	149,259	172,721
Switzerland.....	126,343	142,082	470,934	563,002
Great Britain.....	345,292	623,732	600,583	1,072,463
Canada.....	358	1,230	16,707	22,773
Czecho-Slovakia.....	18,417	17,101	21,256	25,281
Japan.....	.....	.....	4,380	5,199
Poland.....	.....	.....	54,732	56,034
Spain.....	.....	.....	10	15
Yearly totals.....	1,711,987	2,294,558	7,000,521	8,171,093
	1926		1927	
	Pounds	Dollars	Pounds	Dollars
Italy.....	2,389,284	1,911,039	6,795,937	5,632,587
Germany.....	2,578,443	2,607,627	2,629,303	2,543,915
France.....	713,412	591,565	2,814,801	2,230,090
Netherlands.....	2,599,877	2,427,817	2,601,348	2,138,903
Belgium.....	739,509	530,349	585,815	432,025
Austria.....	352,494	268,416	425,630	292,026
Switzerland.....	509,806	495,721	243,479	220,170
Great Britain.....	107,291	157,897	53,773	63,467
Canada.....	.....	.....	49,460	40,774
Hungary.....	25	78	20,123	27,526
Czecho-Slovakia.....	9,734	8,404	1,238	1,213
Japan.....	.....	.....	757	956
Poland.....	13,093	15,593	.....	.....
Spain.....	50,100	36,159	.....	.....
Argentine.....	.....	.....	880	800
Yearly totals.....	10,063,068	9,050,665	16,222,534	13,623,352

IMPORTS OF RAYON YARN INTO U.S. SHOWING MONTHLY COMPARISON BY COUNTRIES

per country)



* Includes all Rayon Yarn Imports into the United States.

CHART 23. All Imports, by Months, of Rayon Yarn into the United States: (Bureau of Foreign and Domestic

TOTAL IMPORTS OF RAYON INTO U.S. BY DENIER
PERIOD 1927-1928.

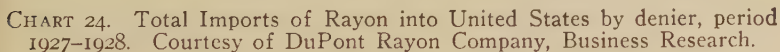


TABLE 53A: TOTAL IMPORTS OF RAYON INTO U. S.—1927. BY DENIER

Den.	January	February	March	April	May	June	July	August	September	October	November	December
30	.....	.....	.....	.....	.....	19	.....	.....	.....	.....	.....	.....
35	.....	50	21	.....	.....	19	.....	566	.....	225	580	622
40	2,200	8,151	.....	212	.....	19	1,540	.....	1,956	906	.....	30
45	227	308	1,164	.....	198	1,021	220	1,957	679	693	1,864	1,470
50	.....	.....	.....	476	.....	.....	221	.....	.....	.....	.....	50
55	.....	47	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
60	4,641	8,818	20	3,955	4,061	2,182	.....	.....	2,205	.....	.....	.....
65	.....	46	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
75	7,068	17,420	1,205	4,643	4,259	3,260	1,981	2,223	4,840	1,824	2,453	2,172
80	1,980	220	5,509	1,100	8,157	4,076	5,284	6,171	266	440	.....	2,183
85	9	.....	218	4	876	4,420	218	.....	.....	.....	.....	.....
90	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
100	1,089	220	5,727	1,104	9,033	8,496	5,502	6,171	266	440	.....	2,183
110	.....	.....	2,183	.....	5,020	437	.....	.....	.....	4,365	1,310	5,556
120	3,723	3,525	4,117	7,657	11,666	3,293	440	2,952	1,100	10,983	581	880
130	.....	.....	.....	.....	.....	9,046	3,804	.....	.....	.....	3,740	.....
140	3,723	3,525	6,300	7,657	16,774	12,776	4,304	2,952	1,100	15,348	5,631	6,436
150	461,453	592,823	820,141	972,608	1,259,351	1,067,041	960,497	1,259,637	958,311	1,109,926	1,011,768	1,472,737
300	83,921	129,528	242,875	113,912	305,528	116,089	132,331	156,055	95,165	169,941	138,138	161,898
450	4,147	3,958	12,214	20,161	6,884	6,788	.....	.....	.....	1,100	5,884	36,280
120	17,138	6,004	4,809	11,487	9,451	7,673	12,847	5,753	11,572	12,550	16,685	11,131
140	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	218	.....
160	.....	.....	220	880	.....	.....	.....	.....	440	220	220	660
170	2,200	.....	.....	1,320	.....	.....	.....	.....	.....	.....	.....	.....
180	4,025	1,310	218	2,268	.....	.....	1,180	49	110	.....	2,205	.....
190	.....	.....	.....	.....	271	.....	.....	.....	.....	.....	.....	.....
200	5,043	660	2,401	22,422	34,010	660	660	2,200	220	740	.....	.....
240	.....	.....	.....	655	.....	.....	.....	.....	.....	.....	.....	.....
250	.....	.....	.....	.....	2,207	.....	1,102	.....	.....	.....	.....	.....
270	.....	2,408	1,093	2,040	.....	.....	.....	.....	.....	.....	.....	.....
290	.....	.....	.....	.....	270	.....	.....	.....	.....	.....	.....	.....
350	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
360	.....	595	.....	27,500	.....	123	22,000	.....	.....	.....	.....	.....
500	660	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
590	436	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
660	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
900	.....	.....	.....	.....	.....	.....	880	.....	.....	.....	.....	.....
913	.....	.....	.....	.....	2,888	.....	2,888	.....	.....	.....	.....	.....
1200	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20,592	.....	10,977	8,741	68,572	48,827	8,456	41,557	8,002	12,342	13,510	19,328	11,791

TABLE 53B: TOTAL IMPORTS OF RAYON INTO U. S.—1928. BY DENIER

Den.	January	February	March	April	May	June	July	August	September	October	November	December
30							656	1,322		1,151		
35	2	1,617	938	1,069	474	508		1,322		1,151		
40		47		10		453	1,017	538		5,606	286	
45		904	694	891		1,382	1,924	3,309		5,606	4,494	
50						910	2,487	13,185		1,821	3,194	
55												
60				44	240					218	5,749	
70										3,112	7,776	
	2	2,568	1,632	2,014	714	3,253	6,084	18,354	5,551	14,437	21,499	
75	171		60	2,205	440	4,650	13,728	16,306		29,805	28,012	
80				44	1,450	1,582	2,411	10,763		2,613	14,197	
	171		60	2,249	1,890	6,232	16,139	27,069	32,356	32,418	42,209	
85					2,183	8,731	30,556	6,540		4,365		
90		3,307	3,305	12,338	29,318	7,275	1,310	1,310		10,142	6,615	
100	10,782	5,065	17,544	22,030	81,477	97,570	124,930	102,631		131,501	101,529	
	10,782	8,372	20,849	34,368	112,978	113,576	157,601	110,490	84,094	146,008	108,144	
150	1,148,918	911,816	711,684	406,446	487,804	523,907	583,888	787,559	721,780	949,805	702,941	
300	85,905	104,603	202,278	197,967	139,632	97,187	32,387	5,724	3,370	5,886	4,488	
450		1,091	15,377	1,540	6,548	1,320					1,100	
120	18,681	9,033	13,201	7,333	34,073	15,847	25,848	12,860	16,452	16,705	17,535	
140						20				2,205		
160	220	220	220	220	220	220		220		220		
170											90	
180	11,231	9,700										
190												
200	200	1,091	448	440	660	5,905	3,183	440		11,773	9,673	
240												
250	250	220	8,764	1,311	4,487	2,205	5,483			5,722	6,600	
270		1,964		10,913	50,854							
200												
350											99	
400	1,148,918							88				
450								218				
500												
550								66				
600								66				
900		1,141			5,507							
913												
Not *d.												
	30,132	23,623	22,633	20,225	100,045	443	34,515	13,958	16,452	36,625	34,017	

production, imports and exports of the different countries will now be given in the tables which follow. The Rayon producing companies to be thus considered are: Brazil, Italy, England, Germany, France, Holland, Belgium, Switzerland, Austria, Czecho-Slovakia, Poland, Spain and Japan.

BRAZIL

TABLE 54.—PRODUCTION, IMPORTS AND EXPORTS, OF RAYON FOR BRAZIL, POUNDS

Year	Production	Imports	Exports
1926	220,000	3,500,000	
1927	350,000	5,000,000	
1928	880,000	500,000	

As noted in the above table Brazil imports most of its Rayon yarn which it will do from year to year unless capital will be invested in producing plants. This however, will be a slow process due to the fact that chemicals are yet lacking.

ITALY

It will be noted that an entire change has come about in Italy's Rayon markets. In 1927 shipments to Great Britain fell to only 520,000 pounds as against 4,400,000 pounds in 1925, and to Japan from 1,500,000 pounds in 1926 to 210,000 pounds in 1927. Italy has turned its attention to other markets and sales to Germany, India and China increased phenomenally.

TABLE 55.—PRODUCTION, EXPORTS AND IMPORTS OF RAYON FOR ITALY, POUNDS

Year	Production	Exports	Imports
1922	6,300,000	3,200,000	900,000
1923	10,100,000	5,000,000	1,100,000
1924	18,500,000	10,000,000	1,300,000
1925	30,000,000	16,000,000	1,250,000
1926	35,000,000	21,500,000	1,700,000
1927	37,000,000	26,000,000	1,000,000
1928	45,000,000	28,500,000	1,000,000

TABLE 56.—DISTRIBUTION OF EXPORTS FROM ITALY BY YEARS, POUNDS

Country	1922	1923	1924	1925	1926	1927
Austria.....	73,000	165,000	1,600,000	730,000	750,000	1,000,000
Belgium.....	8,000	30,000	20,000	80,000	840,000	670,000
France.....	120,000	205,000	1,400,000	370,000	440,000	80,000
Germany.....	242,000	265,000	440,000	1,600,000	5,500,000	6,250,000
Great Britain....	198,000	1,830,000	3,500,000	4,400,000	860,000	520,000
Spain.....	500,000	80,000	440,000	580,000	990,000	610,000
Switzerland.....	1,408,000	1,300,000	840,000	770,000	660,000	1,000,000
China.....	.....	242,000	480,000	950,000	2,600,000	2,900,000
Japan.....	.....	48,000	110,000	400,000	1,500,000	210,000
India.....	.....	66,000	260,000	1,000,000	2,900,000	3,400,000
United States....	572,000	500,000	220,000	3,300,000	2,200,000	4,900,000
Other countries..	79,000	269,000	690,000	1,820,000	2,260,000	4,460,000
Totals.....	3,200,000	5,000,000	10,000,000	16,000,000	21,500,000	26,000,000

Exports to these three countries in 1927 represented 47.5 per cent of the total. Sales to Germany alone were 6,250,000 pounds or almost four times the 1925 figure. Exports to India jumped from 1,000,000 pounds in 1925 to 3,400,000 pounds in 1927; and to China from 950,000 pounds in 1925 to 2,900,000 pounds in 1927. Thus did Italian Rayon manufacturers re-establish the balance during the period when their industry was seriously threatened with the ills of overproduction.

THE RAYON INDUSTRY

ENGLAND

TABLE 57.—PRODUCTION, IMPORTS AND EXPORTS FOR ENGLAND OF RAYON,
POUNDS

Year	Production	Imports	Exports
1925	28,000,000	11,800,000	7,202,709
1926	25,500,000	2,300,000	5,838,870
1927	36,000,000	2,250,000	8,358,141
1928	52,000,000	2,612,000	9,543,325

The distribution of Great Britain's Rayon exports is not available since 1926, therefore the following table shows the principal markets for that year for single yarns amounting to 5,312,674 pounds.

TABLE 58.—PRINCIPAL BRITISH MARKETS FOR YEAR 1926

	Pounds
Australia.....	1,181,619
British India.....	500,375
Other Empire markets.....	240,546
Japan.....	779,641
Spain.....	582,137
Brazil.....	293,830
Sweden.....	273,843
Denmark.....	233,195
Other foreign markets.....	1,227,488
Total.....	5,312,674

TABLE 59.—DISTRIBUTION OF GREAT BRITAIN'S RAYON IMPORTS FOR 1926

	Pounds	Per Cent
Netherlands.....	966,000	42.0
Italy.....	747,500	32.5
Switzerland.....	223,100	9.7
Belgium.....	144,900	6.3
Germany.....	98,900	4.3
Others.....	119,600	5.2
Total.....	2,300,000	100.0

GERMANY

TABLE 60.—PRODUCTION, IMPORTS AND EXPORTS FOR GERMANY OF RAYON, POUNDS

Year	Production	Imports	Exports
1924	23,700,000	2,200,000	
1925	27,100,000	4,100,000	
1926	26,000,000	10,000,000	8,200,000
1927	35,500,000	17,600,000	8,200,000
1928	41,000,000	18,700,000	13,200,000

Germany was among the first countries of Europe to benefit from the development of Rayon, which first saw daylight in France in 1880, through the ingenuity of Count Hilaire de Chardonnet. The German people, particularly due to the necessities of the Great War, took to Rayon wearing apparel to the exclusion of real silk. Table 60 shows that Germany not only keeps most of what she produces, but imports a large quantity. What Germany is really doing is to export her finer qualities yarn and import for her own use the cheaper grades of other countries, a large quantity of which is shipped into Germany from Italian Rayon mills.

FRANCE

TABLE 61.—PRODUCTION, IMPORTS AND EXPORTS FOR FRANCE OF RAYON YARN, POUNDS

Year	Production	Imports	Exports
1924	12,300,000	3,918,200	303,600
1925	14,400,000	1,929,400	1,399,600
1926	17,500,000	2,168,000	2,396,700
1927	19,800,000	835,500	10,653,300
1928	30,000,000	1,200,000	11,700,000

THE RAYON INDUSTRY

France's efforts are directed toward increasing its export markets and the above figures indicate quite clearly this effort.

HOLLAND

TABLE 62.—PRODUCTION, IMPORTS AND EXPORTS FOR HOLLAND OF RAYON,
POUNDS

Year	Production	Imports	Exports
1924	3,400,000	578,000	
1925	4,400,000	1,004,000	6,263,000
1926	13,500,000	2,600,000	11,715,000
1927	16,500,000	.....	15,300,000
1928	16,500,000	915,000	16,722,000

Holland is again an exporting country. Almost the entire production of 1926 and 1927 was shipped to foreign countries.

TABLE 63.—PRODUCTION, IMPORTS AND EXPORTS FOR BELGIUM, OF RAYON,
POUNDS

Year	Production	Imports	Exports
1924	8,900,000	275,000	
1925	11,100,000	590,000	
1926	13,100,000	900,000	7,000,000
1927	13,500,000	1,100,000	8,800,000
1928	15,000,000	647,000	6,200,000

BELGIUM

Belgium, producing a high-grade Rayon yarn, is developing foreign markets and a large portion of its Rayon is sold abroad.

SWITZERLAND

TABLE 64.—PRODUCTION, IMPORTS AND EXPORTS FOR SWITZERLAND
OF RAYON, POUNDS

Year	Production	Imports	Exports
1924	4,000,000	3,200,000	2,325,000
1925	5,500,000	2,740,000	4,116,000
1926	8,000,000	2,220,000	6,500,000
1927	9,000,000	3,615,000	7,260,000
1928	12,000,000	2,500,000	5,750,000

Switzerland, a country which has always been a factory for the entire world, is doing the same thing with its new product, Rayon.

AUSTRIA

TABLE 65.—PRODUCTION, IMPORTS AND EXPORTS FOR AUSTRIA
OF RAYON, POUNDS

Year	Production	Imports	Exports
1925	3,500,000	1,920,000	2,343,000
1926	3,500,000	1,880,000	3,318,000
1926	3,500,000	1,880,000	3,318,000
1927	3,500,000	2,000,000	3,000,000
1928	4,500,000	.....	.....

Austria is exporting finished Rayon goods which accounts, in this case, for its large amount of exports.

CZECHO-SLOVAKIA

TABLE 66.—PRODUCTION, IMPORTS AND EXPORTS FOR CZECHO-SLOVAKIA
OF RAYON, POUNDS

Year	Production	Imports	Exports
1924	1,300,000		
1925	2,000,000		
1926	2,800,000	3,788,000	1,555,000
1927	3,500,000	5,300,000	5,000,000
1928	3,500,000	5,500,000	1,200,000

THE RAYON INDUSTRY

Czecho-Slovakia is also a manufacturer of wearing apparel which is exported in large quantities.

POLAND

TABLE 66A.—PRODUCTION, IMPORTS AND EXPORTS FOR POLAND, OF RAYON.
POUNDS

Year	Production	Imports	Exports
1924	1,500,000		
1925	2,200,000		
1926	2,000,000	.....	1,500,000
1927	4,000,000	250,000	1,000,000
1928	7,500,000	1,000,000	500,000

Poland, with American financial backing, is increasing its output of Rayon yarn. Its textile mills will continue to use increased quantities of Rayon.

SPAIN

TABLE 67.—PRODUCTION, IMPORTS AND EXPORTS FOR SPAIN, OF RAYON,
POUNDS

Year	Production	Imports	Exports
1924	200,000		
1925	200,000		
1926	300,000	3,800,000	
1927	1,000,000	4,200,000	
1928	2,500,000		

Spain needs considerably more Rayon than it produces. It imports many times its productive capacity.

JAPAN

TABLE 68.—PRODUCTION, IMPORTS AND EXPORTS FOR JAPAN OF RAYON,
POUNDS

Year	Production	Imports	Exports
1924	1,200,000		
1925	1,400,000		
1926	5,500,000	3,500,000	
1927	9,000,000	3,000,000	
1928	12,000,000	256,120	67,984

Japan, curiously enough, commenced its production a few years ago, to meet eventually a world demand, but its own people took to this yarn to such an extent that its own production is not sufficient, and recourse is had to importation of a few million pounds annually.

As a résumé of exports and import trade returns, we add here Table 69 giving these figures in metric tons, for certain of the Rayon producing countries. These figures like the previous ones, while obtained from responsible sources, cannot be considered but approximate. They are, however, of sufficient value to plan forecasts of the industry.

TENDENCIES TOWARDS CONSOLIDATION

There exists always a natural tendency to unite forces for protection, and industry is no exception to the rule. The Rayon industry has not yet reached a stage where competition has to any great extent forced such handling together of interests because the demand always has been, and will be for a long time to come, far in advance of the supply.

The consolidations which exist today in this industry are due more to the specialized and highly technical conditions surrounding it and intimately related to it than to any great

THE RAYON INDUSTRY

TABLE 69.—PRODUCTION, * IMPORTS AND EXPORTS OF CERTAIN COUNTRIES, METRIC TONS

Country	1923	1924	1925	1926
Exports:				
Austria.....	0.7	0.9	1.06	1.51
Belgium †.....			3335.0	3220.0
France.....	220.0	138.0	636.0	1089.0
Germany.....	1575.0	2348.0	3797.0	3661.0
Great Britain ‡.....			3267.0	2648.0
Holland.....	1755.0	2555.0	3042.0	5543.0
Hungary.....		294.0	279.0	183.0
Italy.....	2181.0	3758.0	4361.0	5707.0
Poland.....		99.0	160.0	107.0
United States §.....			68.0	181.0
Imports:				
Argentina.....		158.0	585.0	740.0
Austria.....	0.36	0.66	0.87	0.85
Belgium ||.....			147.0	509.0
Brazil ¶.....	1.5	4.3	6.8	13.5
Bulgaria.....	4.2	21.7	42.3	53.8
China.....	500.0	783.0	1634.0	2567.0
Denmark ○.....			96.0	214.0
Egypt.....			162.0	235.0
France.....	775.0	1781.0	878.0	985.0
Germany.....	268.0	1086.0	2040.0	4542.0
Great Britain †.....			5343.0	1044.0
Holland.....	68.0	153.0	286.0	497.0
Hungary.....		70.0	80.0	234.0
India □.....	72.0	531.0	1210.0	2620.0
Italy.....	507.0	569.0	577.0	756.0
Japan ○.....	458.0	407.0	375.0	1495.0
Mexico.....	23.3	19.8	21.8	28.8
Persia.....			0.3	0.6
Poland.....		172.0	94.0	66.0
Spain.....	535.0	602.0	1122.0	1646.0
Sweden.....	48.0	170.0	536.0	472.0
United States.....	3120.0	3236.0	5685.0	6668.0

* From Times Trade and Engineering Supplement, London.

† In 1927 exports totalled about 3575 tons, largely to Germany.

‡ Figures are on a comparable basis during the past three years only; in 1927 exports were 3783 metric tons and imports 1225 metric tons.

§ Figures for 1923 and 1924 are not available.

|| In 1927 imports totalled about 610 tons, mainly from France and Italy.

¶ The returns are classified as manufactures of vegetable silk "but not including vegetable silk piece goods," imports of which were 2.6 tons in 1923, 7.8 tons in 1924, 13.0 tons in 1925, and 19.5 tons in 1926.

○ Imports in 1927 were 436 tons.

□ Imports during the first six months of the present financial year—namely, from April 1 to Sept. 30, showed a further substantial advance at 1856 metric tons.

○ The returns are entered under "artificial silk," which may embrace yarn and fabrics.

In the above table it has been impossible to include figures relating to a few of the producing countries and several large importing countries because their official statistics do not give separate returns for artificial silk yarn. Among such countries may be mentioned Czechoslovakia, Switzerland, Spain, Japan, Canada, New Zealand, South Africa, British Malaya, Chile, and most of the Latin-American countries. Canada's imports of "artificial silk fabrics and filaments or artificial fibre silk yarns produced by cellulose process" in 1925 and 1926 were over 750 tons. The Czechoslovak trade returns combine "yarns and woven artificial silk," imports of which totalled in 1925 and 1926 about two and a half times the volume of exports. The Swiss returns include fabrics as well as yarns, exports of which in 1926 were 3000 tons and imports 1100 tons. Ceylon's imports of "artificial silk" quadrupled between 1925 and 1926, but how much was yarn is not stated. Australia's imports of artificial silk yarn were not recorded until 1926, when they totalled £349,000 in value, the quantities not being stated.

necessity because of competition. The profits derived from the production of Rayon have been so large that those controlling the earliest companies had all the desire in the world to continue such control and to expand with the growing demand. On the other hand, those wishing to enter the industry at a later date found it to their interests to associate with them the older companies because of their experience, and of the technical aid obtainable from such associations.

In this manner were developed group associations built up in most instances round a particular process of producing Rayon or particular methods of applying such process. These group associations are today international in scope and tremendously wealthy and have been the means of greatly increasing the quality of Rayon yarn.

The various countries producing Rayon may be divided roughly into importing and exporting countries as can readily be seen by a perusal of the foregoing information in this chapter, and while there has been some slight competition among the exporting countries, none of them have had difficulty in finding markets for their product. Probably the first instances of competition were felt by the Vereinigte Glanzstoff Fabriken A. G. of Germany when they were faced by the large imports of Rayon of an inferior quality from Italy. As a result of this condition there arose the consolidation of interests between the German Company and the "Snia" of Italy, thus forming the basis of the now well-known European cartel of which Courtaulds Ltd. of England is the third member.

When the time arises and supply meets demand, and competition becomes keen, such cartels as the Glanzstoff-Snia-Courtauld will wield tremendous power in the development of conditions. Today this cartel, through its many ramifications, has brought only good to the industry itself, as well as to

those other industries allied with it and to those financially interested in the production of Rayon.

The future will doubtless develop other consolidations which in turn will be able, by a combination of capital and technical experience, to carry on research work on a large scale, both in the methods of producing Rayon and in the machinery used. All of which will in the final analysis not only continue the tremendous progress made in the past few years in the quality of Rayon yarns for those uses to which it is now put, but will develop products of cellulose which will enable the industry to expand until it is the leader among the textiles.

In the two following charts, 25 and 26, we show by different methods of presentation the various consolidations and group controls in the world production of Rayon.

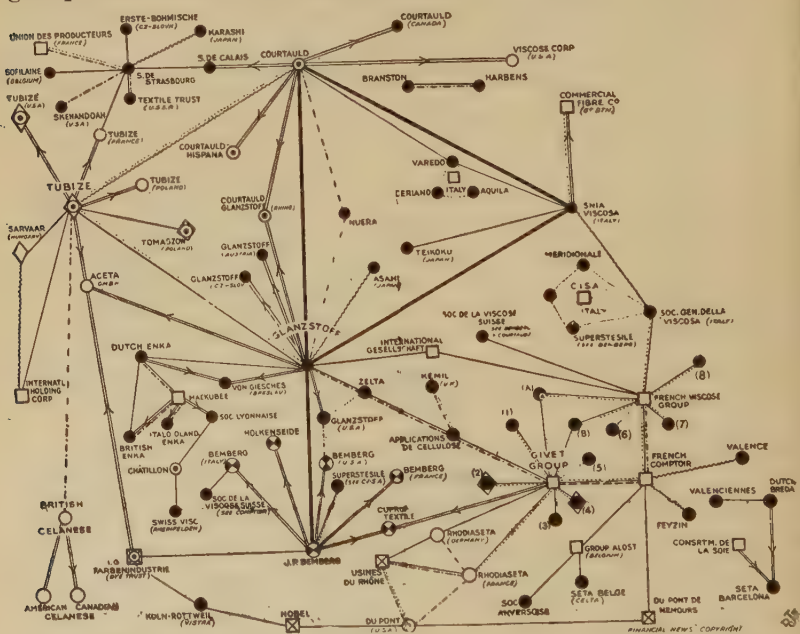


CHART 25. Consolidations and Group Control of Rayon Companies (from Financial News, London).

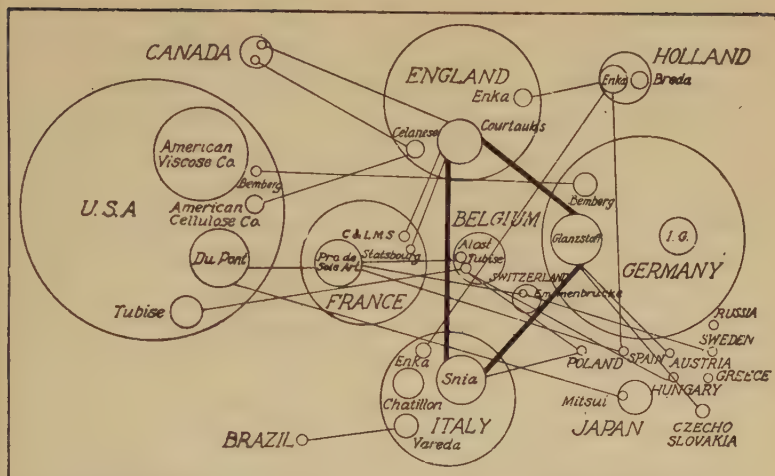


CHART 26. Group Control of Rayon Companies. (From Textile Mercury, England.)

Tariffs

Prior to the tariff act of 1909, in which Rayon was first specifically mentioned, there was no artificial silk industry in this country. Later, growth was stimulated by the almost complete stoppage of imports from Europe during the War. The suspension of production within the war zone, the difficulties encountered by other foreign producers in obtaining labor and raw materials, and the increased demand abroad for textile-fibre substitutes, cut the surplus of the European Rayon industry during the War. Imports which began to slump sharply in 1916, continued to decline for two years and amounted to only 121,000 pounds in 1918 as compared with 2,306,000 pounds in 1913. With the European supply practically cut off, the American industry was given the chance to dominate the domestic market, but the greatest expansion has occurred since the War.

The imposition of duties on Rayon has not suppressed importations under normal trade conditions, largely

because of the need of an additional supply to supplement the domestic output. The American Rayon industry places its entire output with consumers in this country. No attempt has been made to develop an export trade, since the home market has a greater consuming capacity than it has been able to satisfy. Although foreign supplies are drawn upon to make up the deficiency, the imported ratio, in relation to the total supply available for domestic consumption, has decreased year by year. In 1913 imports amounted to approximately 60 per cent of the total supply, while in 1924 the ratio was slightly less than 5 per cent.

Rayon was not separately provided for in the Tariff acts of the United States until the act of 1909. There had been imports of this commodity for more than 12 years prior to this act, but the quantities were of no commercial importance. Such shipments as did come in were assessed at different rates according to different rulings of the Courts and the Board of General Appraisers. Since the earliest imports of Rayon into the United States were produced by the Chardonnnet, or nitro-cellulose process, they were classified as "finished or partly finished articles of which collodion or any compound of pyroxylin is the component of chief value" and hence were assessed at 45 per cent ad valorem under the act of 1894 and 65 cents per pound plus 25 per cent ad valorem under the act of 1897.

However, when non-nitrated Rayons appeared, which could not be classified as pyroxylin, they were classed as "similar in texture and quality" to silk and were accordingly assessed at 30 per cent ad valorem. Later, this decision was appealed and a classification "similar to cotton yarns" was sustained by the United States Supreme Court, which held until a specific provision was made for Rayon in the act of 1909.

The act of 1909 made an attempt to classify Rayons into

singles, trams and organzine, depending for similitude on the complexity of thread structure which prevails in raw silk, and the assessment was placed at 40 cents per pound for "singles," 50 cents per pound on "tram," and 60 cents per pound on "organzine." These terms are, of course, not in accord with trade usage and were confusing in their interpretation.

In the act of 1913 no attempt was made to classify Rayon and it imposed a flat rate of 35 per cent ad valorem on all Rayon yarns. The tariff act of 1922 applies specific rates on single and ply yarns of 45 and 50 cents per pound, respectively, and provides further that in no case shall a rate equal to less than 45 per cent ad valorem apply. Based on prevailing schedules of prices the rates which are now applied are higher and the ad valorem rates are hence no more applied as they had been until recently prior to the recession of prices.

TABLE 70: UNITED STATES RATES OF DUTY ON RAYON YARNS AND ARTIFICIAL HORSEHAIR

Act of	Para- graph	Tariff Classification or Description	Rates of Duty, Specific and Ad Valorem
Aug. 5, 1909	405	Yarns, threads, filaments of artificial or imitation silk, or of artificial or imitation horsehair, by whatever name known, and by whatever process made, If in the form of singles..... If in the form of tram..... If in the form of organzine..... <i>Provided</i> , That in no case shall any yarns, threads, or filaments of artificial or imitation silk or imitation horsehair, or any yarns, threads, and filaments made from waste of such materials, pay a less duty than.....	45 cents per pound 50 cents per pound 60 cents per pound 30 per centum ad valorem
Oct. 3, 1913	319	Yarns, threads, filaments of artificial or imitation silk, or of artificial or imitation horsehair, by whatever name known, and by whatever process made.....	35 per cent ad valorem
Sept. 21, 1922	1213	* * * yarns, threads, and filaments of artificial or imitation silk, or of artificial or imitation horsehair, by whatever name known, or by whatever process made, If singles..... If advanced beyond the condition of singles by grouping or twisting two or more yarns together..... * * * but none of the foregoing yarns, threads, or filaments, * * * shall pay a less rate of duty than.....	45 cents per pound 50 cents per pound 45 per centum ad valorem

Germany...	fices as a filament, a number of which run together form the thread or yarn, 300-denier. Artificial-silk yarn manufactured or spun from waste of artificial silk.	None found	.do..	1.022	.05	319	35	.357	19.5	.28	1.709	.....	21	1215	60 cts. per pound.	405	60 cts. per pound.
Switzerland.	Artificial-fibre silk sweater of 300-denier yarn.	Same as foreign.	Each	2.84	.28	319	60	1.70	45.2	2.18	7.00	7.35	59	1215	45 cts. per pound and 37½ per cent.	405	45 cts. per pound and 60 per cent.
England....	Cotton and artificial silk dress goods, 40 inches wide; warp, 174 threads per inch; artificial silk, 150-inches wide; warp, 169 threads per inch cotton, 40/2; weight, square yard, 5.32 ounces, embossed.	Cotton and artificial goods, 40 inches wide; warp, 169 threads per inch artificial silk, 140-denier; weight, 46 threads per inch; cotton, 56/2; weight square yard, 4.25 ounces.	Yard	1.32	.07	319	60	.79	33	.72	2.90	2.57	21	1215	do	...	do ³
France.....	Satin artificial silk-primée 35 inches wide; warp ends, artificial silk, 158; weft, 92 picks orgazine silk, 2.46 ounces per square yard, printed.	None found	do	1.63	.10	319	60	.98	35.1	.96	3.67	.....	21	1215	do	405	do
	None found.....	Artificial silk knitted fabric in piece, 36 inches wide.	do	.....	.....	.....	.....	.....	.....	.....	1.32	59	1215	do	405	do	do

¹ Based on comparative prices of the domestic and foreign product as of Aug. 1, 1921.

² Actual selling price of domestic, \$2.70, on account of domestic being 20 cents per pound higher than foreign.

³ Actual selling price, domestic, \$2.10, on account of superiority of foreign and the fact that foreign is embossed.

The following is a comparison of United States tariff rates on articles made of Rayon as fixed in the various acts from 1909 to 1913:

TABLE 72. MANUFACTURES OF RAYON, ARTIFICIAL HORSEHAIR, VISCA, AND CELLOPHANE—RATES OF DUTY

Act of	Para-graph	Tariff Classification or Description	Rate of Duty
1909	405	* * * braids, laces, embroideries, galloons, neck ruffings, ruchings, fringes, trimmings, beltings, cords, tassels, ribbons, or other articles or fabrics composed wholly or in chief value of yarns, threads, filaments, or fibers of artificial or imitation silk or of artificial or imitation horsehair, by whatever name known, and by whatever process made.	45 cents per pound, and in addition thereto, 60 per centum ad valorem
	350	Laces, embroideries, edgings, insertings, galloons, flouncings, nets, nettings, trimmings, and veils, composed of * * * artificial silk * * *, made on the Lever or go-through machine.	70 per centum ad valorem.
1913	319	* * * beltings, cords, tassels, ribbons, or other articles or fabrics composed wholly or in chief value of yarns, threads, filaments, or fibers of artificial or imitation silk or of artificial or imitation horsehair, or of yarns, threads, filaments, or fibers of artificial or imitation silk, or of artificial or imitation horsehair and India rubber, by whatever name known, and by whatever process made.	60 per centum ad valorem.
	358	Laces, lace window curtains not specially provided for in this section, coach, carriage, and automobile laces, and all lace articles of whatever yarns, threads, or filaments composed; handkerchiefs, napkins, wearing apparel, and all other articles or fabrics made wholly or in part of lace or of imitation lace of any kind; embroideries, wearing apparel, handkerchiefs, and all articles or fabrics embroidered in any manner by hand or machinery, whether with a plain or fancy initial, monogram, or otherwise, or tamboured, applique, or scalloped by hand or machinery, any of the foregoing by whatever name known; edgings, insertings, galloons, nets, nettings, veils, vellings, neck ruffings, ruchings, tuckings, flouncings, flutings, quillings, ornaments; braids, loom woven and ornamented in the process of weaving, or made by hand, or on any braid machine, knitting machine, or lace machine, and not specially provided for; trimmings not specially provided for; woven fabrics or articles from which threads have been omitted, drawn, punched, or cut, and with threads introduced after weaving, forming figures or designs, not including straight hemstitching; and articles made in whole or in part of any of the foregoing fabrics or articles; all of the foregoing of whatever yarns, threads, or filaments composed.	do
1922	1213	* * * Knit goods, ribbons, and other fabrics and articles composed wholly or in chief value of any of the foregoing.*	45 cents per pound and 60 per centum ad valorem.
1922	1430	Laces, lace window curtains, burnt-out laces and embroideries capable of conversion into burnt-out laces, nets and nettings, embroidered or otherwise, veils, vellings, flouncings, all-overs, neck ruffings, flutings, quillings, ruchings, tuckings, insertings, galloons, edgings, trimmings, fringes, gimps, ornaments; braids, loom woven and ornamented in the process of weaving, or made by hand, or on any braid machine, knitting machine, or lace machine; and all fabrics and articles composed in any part, however small, of any of the foregoing fabrics or articles; all the foregoing, finished or unfinished (except materials and articles provided for in paragraphs 920, 1006, 1404, 1406, and 1424 of this Act), by whatever name known, and to whatever use applied, and whether or not named, described, or provided for elsewhere in this Act, when composed wholly or in chief value of yarns, threads, filaments, * * * or products of cellulose provided for in paragraph 1213 of this Act.	90 per centum ad valorem.
		Embroideries not specially provided for, and all fabrics and articles embroidered in any manner by hand or machinery, whether with a plain or fancy initial, monogram, or otherwise, or tamboured, applique, scalloped, or ornamented with beads, bugles, or spangles, or from which threads have been omitted, drawn, punched, or cut, and with threads introduced after weaving to finish or ornament the open-work, not including straight hemstitching; all the foregoing, finished or unfinished, by whatever name known, and to whatever use applied, and whether or not named, described, or provided for elsewhere in this Act, when composed wholly or in chief value of yarns, threads, filaments, * * * beads, bugles, spangles, or products of cellulose provided for in paragraph 1213.	75 per centum ad valorem.

* The "foregoing" refers to artificial or imitation silk, artificial or imitation horsehair, and products of cellulose not compounded, whether known as visca, cellophane, or by any other name.

TABLE 73. TARIFF RATES ON RAYON FOR 9 PRINCIPAL FOREIGN COUNTRIES

Tariff No.	Tariff Classification or Description	Rate of Duty		
		General Tariff		
	GERMANY	Gold marks per 100 kilograms		
394	Artificial silk: Not twisted or only once twisted— Not dyed.....		30.00	
	Dyed (even if dyed white).....		60.00	
395	Twice twisted, dyed or not.....		90.00	
	ITALY	Gold lire per kilogram		
249	Artificial silk in threads: (a) Raw— (1) Single in thread or lametta.....		1.50	
	(2) Double or twisted.....		2.00	
	(b) Dyed— (1) Single.....		1.75	
	(2) Twisted.....		2.25	
	POLAND	Zloty (gold franc)		
	(a) Spun, undyed.....		1100.00	
	(b) Twisted; dyed or any other silk twisted twice or more.....		1400.00	
	CZECHOSLOVAKIA ¹	Kronen per 100 kilograms		
244	Artificial silk, twisted or not: (a) Natural white, not dyed.....		Free	
	(b) Dyed— (1) Black.....		95.00	
	(2) Other colors.....		120.00	
	AUSTRIA ²	Free		
	Artificial silk, twisted or not: (a) Natural white, not dyed.....		Free	
	(b) Dyed.....		95.00	
	BELGIUM	Francs per 100 kilograms		
Ex. 24	Thread and yarn for retail trade, ³ floss silk and artificial-silk yarn.....		1150.00	
	JAPAN	Yen per 100 kin		
290	Artificial silk.....		87.90	
	SWITZERLAND	Francs per 100 kilograms		
446a	Raw artificial silk, not artificially colored.....		2.00	
446b	Other.....		50.00	

Tariff No.	Tariff Classification or Description	General	Minimum	Rate to United States
	FRANCE ⁴	Francs per 100 kilograms	Francs per 100 kilograms	Francs per 100 kilograms
381b	Thread of artificial silk, pure, single unbleached.....	2000.00	500.00	750.00
	Dyed or thrown.....	2600.00	650.00	975.00
	Mixed.....	(5)	(5)	(5)

¹ Coefficient 13 to be applied to rates to give new duties.² Duty payable in bank notes at a fixed number of times the prescribed gold duty. The conversion is fixed periodically by the Austrian authorities.³ Yarns not prepared for retail trade are free if of silk or floss silk, but no mention is made of artificial silk.⁴ Amount of specific duty on unbleached yarn to be multiplied by coefficient 2.5, result representing amount to be paid; coefficient 3 for dyed and 3.5 for thrown artificial yarns.⁵ Same duty as on the most highly taxed portion of the mixture.

TABLE 74. COMPARATIVE ANALYSIS OF IMPORTANT DUTIES OF 10 PRINCIPAL COUNTRIES
PRODUCING RAYON YARNS, RATES EFFECTIVE 1924
Basic Rate for Unbleached Singles

Country	Tariff No.	BASIC ASSESSMENT		CONDITIONS OR PROCESSES PAYING ADDITIONAL OTHER THAN BASIC RATE					Comments
		Specific or Ad Valorem	Specific		Bleached	Dyed	Doubled, Twisted, or Thrown	Finished for Retail Trade	
			Basic Unit of Quantity	Basic Rate					
United States..	1213	Specific with minimum ad valorem proviso	Pound	45 cents	.....	.....	Plus 5 cents	.....	None of the enumerated yarns shall pay a less rate than 45 per cent ad valorem.
Germany.....	394-395	Specific	100 Kilo-grams	30 marks ¹	Plus 30 marks.	Plus 30 marks	Plus 60 marks	Plus 270 marks ²	Stated in gold marks, payable in paper at official rate of exchange for date of payment.
Austria.....	194	do	do	Free	.....	95 kronen ¹	.....	Plus 105 kronen	Duty payable in bank notes at a fixed number of times the prescribed gold duty. Conversion rate is fixed periodically by the Austrian authorities.
Poland.....	185 ³	do	do	1100 zloty (gold francs) ⁽⁴⁾		Plus 300 zloty	Plus 300 zloty	1115 francs	Duty includes coefficient. Coefficient 13 to be applied to rates to give new duties.
Belgium.....	Ex. 24	do	do	Free	.....	.....	.....	.....	Amount of specific duty on unbleached shall be multiplied by coefficient 2.5, result representing amount to be paid. Coefficient 3
Czechoslovakia.	244	do	do	2000, 1 500, ² and 750 ⁶ francs	.....	Plus 600, 150, and 225 francs	Plus 600, 150, and 225 francs	.....	for dyed yarns; 3.5 for doubled yarns.
France.....	381	do	do	.....	.....	.....	.....	.....	
Switzerland....	445-446	do	do	2 francs	.....	Plus 48 francs	Plus 48 francs	Plus 398 francs	Duties paid in paper at a ratio to gold. Conversion rate is fixed weekly by Italian Government.
Italy.....	249	do	do	150 lire	.....	Plus 25 lire	Plus 50 lire	.....	
Japan.....	290	do	100 kin	87.90 yen	.....	.....	.....	.....	

1 General tariff rate.	2 Minimum or conventional rate.	3 Not specified.	4 Black.	5 Other colors.	6 To United States.
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¹ General tariff rate.² Minimum or conventional rate.³ Not specified.⁴ Black.⁵ Other colors.⁶ To United States.

CHAPTER VIII

THE FUNDAMENTAL PRINCIPLES IN RAYON PRODUCTION

THE process of producing Rayon is very similar to that which nature employs in producing real silk. In the Rayon process, as in the natural, the fiber is produced by pressing a viscous mass out of a fine aperture and, by means of a subsequent stretch this is slightly pulled, and finally the coagulated filament is wound in some fitting manner. But instead of having an animal working by instinct, we have, in the Rayon process, machines devised and controlled by the intelligence of man.

The pressing of this viscous mass in continuous filaments through a fine aperture is commonly known as spinning, which as a matter of fact it is not. The filament is not spun as is the case with spun silk or cotton. It is ejected; a term which, while correct, cannot be adopted since, as stated before in this volume, the term spinning has become an expression in general use. In the same way, Rayon yarn is not manufactured; it is made or produced. The use or application of Rayon yarn, in the weaving or knitting processes, conveys the proper use of the term manufacturing Rayon as distinguished from Rayon making.

In order to produce Rayon properly, three things are necessary:

First. A usable spinning solution.

Second. A fitting device or contrivance for forming and

withdrawing the threads, gathering same after they have coagulated or hardened.

Third. A suitable coagulating medium for fixation of the filaments.

THE SPINNING SOLUTIONS

Viscosity.—The foundation of the entire art of Rayon production is a usable spinning solution. It must have the property of tenacity and viscosity so that it can be pulled into fine filaments of great length. It must also have the property of hardening quickly in this form, and besides it must produce a filament of proper strength and elasticity so that it can be handled and used. The solution should further have the desirable characteristic of being of a constant and controllable viscosity under given conditions. It should also have a certain toughness which permits not only the generation of the thread, but its further stretching in this form, without breaking, before reaching its fixation point.

The viscosity of solution is dependent on the molecular structure and attraction of the fluid, and this is influenced by the concentration and the size of the molecules. There are also limits to the viscous properties which dare not be exceeded. For if the viscosity is inordinately increased it would be difficult to force the mass through the fine apertures even with tremendous pressure. And if this were accomplished the speed of thread formation would be too slow for the purposes of commercial production. As a general principle it may be said that those solutions are most desirable which have a sufficient viscosity to give form and strength to the thread, and at the same time possess sufficient fluidity for rapid filament formation.

The measurement of viscosity is discussed by F. Sproxton in his volume on Cellulose Esters.

If we imagine two plane surfaces in a liquid, each of

unit area (one sq. cm.), and 1 cm. apart, forming as it were two opposite surfaces of a cube of the liquid, it is evident that to keep these surfaces moving relatively to each other, each remaining in its own plane, will require more force in some liquids than in others. The inherent property in a liquid which opposes this motion is called its viscosity, and is defined as the tangential force on a unit area of either of two horizontal planes at a unit distance apart required to move one plane with unit velocity in reference to the other plane, the space between being filled with the viscous substance (Bingham, from Clerk-Maxwell). If the force applied is F , the velocity of one plane relative to the other is v , and their distance apart s , the coefficient of viscosity $\eta = \frac{Fs}{v}$.

The viscosity of a liquid is sometimes called its internal friction, and the analogy with solid friction will be apparent, although it must not be taken too far. The viscosity of cellulose-ester solutions increases at a very rapid rate with the concentration, so that in plotting the viscosity-concentration curve it is usual to plot the logarithm of the viscosity instead of the actual number. This has led to the deduction of some interesting empirical equations connecting viscosity and concentration (*v. infra*).

The simplest mechanical illustration of layers of liquid sliding over one another is given by deforming a pack of cards by a shearing stress from the shape illustrated in Fig. 37 (*a*) to the shape illustrated in Fig. 37 (*b*). The experimental measurement of viscosity, however, by a method reproducing the conditions laid down in the definition, would be extremely difficult, and the classic method is by the movement of the liquid in a capillary tube. It is not easy at first to see how this movement realizes the theoretical idea of layers of liquid sliding over one another, but if we take as an illustration, instead of a pack of cards, a rolled-up tape measure, and de-

form it by pushing the center out (Fig. 37 (c)), we see how the movement of liquid in a capillary tube may be regarded as being made up of a series of *concentric* layers moving relatively to each other, the velocity being zero at the circumference (where the liquid touches the tube) and greatest at the center.

The equation connecting the radius of the tube, the head

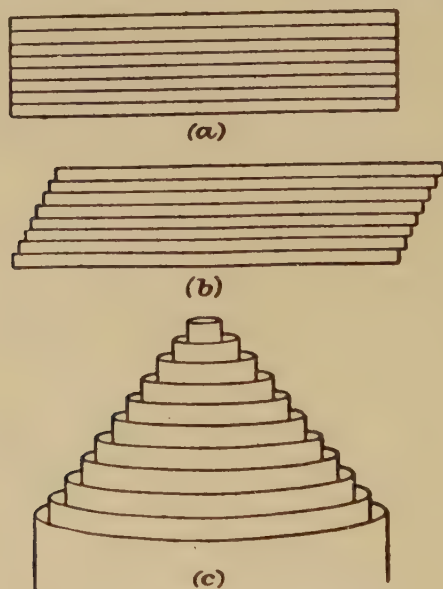


FIG. 37. The Measurement of Viscosity.

of pressure on the liquid, the rate of flow and the viscosity of the liquid is $\eta = \frac{p g R^2}{8 l I^1}$, in which

- p = pressure on the liquid.
- g = acceleration due to gravity.
- R = radius of capillary.
- l = length of tube.
- I = velocity of flow (c.c. per sec.).

It was derived experimentally in another form by Poiseuille in 1842. Poiseuille's original publications are not readily available, but his results have been republished by Bingham, and should be consulted by all those interested in the subject. The accuracy of the agreement with the derived equation is on the whole remarkable.

The measurement of rate of flow in a capillary tube is still perhaps the most widely used method of determining viscosity. For dealing with solutions of very high viscosity, however, there are more convenient methods. One depends on measurement of the rate of fall of a small steel ball through the solution, and makes use of the original mathematical investigation of Stokes. It was developed for cellulose-ester solutions by Sheppard and by Gibson and Jacobs. Others measure the actual friction when one metal cylinder is rotated inside another concentric with it, the space between being filled with the liquid under investigation. Measurements of the viscosity of cellulose esters for technical purposes are usually made either with the Ostwald (capillary tube) (B.E.S.A.) or the falling sphere instruments.

Coagulability.—Not every solution which possesses sufficient viscosity and is capable of being drawn into filaments is spinnable. A solution is only spinnable when it has the property which leaves the filament in a solid state, thus giving it sufficient hardness and strength for gathering and handling. This property is imparted to the filament either by the escape of solvents or by some alteration in the molecular structure. To obtain this fixation of the thread, the filament is drawn through some coagulating medium, either a gas or a liquid.

Strength of Filament Material.—While the properties referred to above are sufficient for the sole purpose of generating a filament, still, for the purposes of further processing, the filaments must have the necessary strength which must, in both the wet and dry state, be great enough so that the yarn

formed of them is usable as a textile material. Unless resulting threads have this ultimate adaptability, they are commercially worthless, even though a solution may have the most desirable properties of viscosity and fluidity.

For example, water glass and casein solutions have been precipitated in suitable baths to threads, but these do not have the necessary toughness and strength. So that after years of experiment and development in the Rayon industry, all materials for solutions have been discarded except cellulose. It is readily understood that the solution must have a certain content of solids in order that the filaments may have the requisite strength. Within certain limits the strength of the thread increases with the concentration of the solution.

A general conclusion cannot be drawn that the higher the concentration of the solution, the greater will be the strength of the thread. This is true only in case of such solutions that differ in content of solids but do not differ in the molecular structure such as we would obtain by the thinning of the same cellulose solution with different masses of solvents. On the other hand, it is not possible to compare solutions of various concentration and different kinds of cellulose combinations because the molecular relationships of the dissolved substances are variable. We know that the conversion of cellulose into a soluble form is accomplished only by the splitting up of the very complex cellulose molecule, and that the solubility of the cellulose increases as the complexity of the molecular structure is decreased; yet as the molecular structure is simplified or broken down the strength of the resulting filament is decreased, hence the goal to be aimed at is to produce a solution of sufficient concentration with the least disturbance to the cellulose molecule.

A certain amount of disturbance of the cellulose molecule is necessary in order to have a solution of suitable viscosity, since viscosity indeed is the direct result of molec-

ular size. From the percentage of cellulose contained in the solution and from its viscosity, an experienced Rayon works manager can quickly judge the usability of a given solution for Rayon production.

THE PREPARATION OF THE SPINNING SOLUTION

The preparation of the solution is dependent upon the special process to be used, so that it is here possible to make only a few general remarks. The ideal solution for continuous Rayon production is one which always has the same composition and the same viscosity. If these properties are held nearly constant the spinning process is uniform and the processing of the threads is considerably simplified. This also influences the general uniformity of the resulting threads.

It is difficult to provide solutions whose percentage composition is constant. Further, it has proved almost impossible even in the largest Rayon works, to produce solutions of continuously constant viscosities. The reason for this is that irrespective of all possible care there is a natural variation in the raw material used, namely, cotton and wood pulp. Variations are almost impossible of detection and are increased and magnified by subsequent chemical treatments.

Filtration.—In order to free the solution of all impurities and suspended matters, the solution must be carefully filtered. Since we are dealing with a highly viscous fluid, it is necessary to employ a vacuum filter or, as is most usually the case, filters of the pressure type. The apparatus most adapted for this purpose is the filter press such as we find in common use in the chemical industry. The filter material must be carefully selected so as to be adaptable to the solution. For this reason different kinds of filter media are used in the different processes.

For the nitro-cellulose and the Viscose processes, it is

customary to use cotton filter-cloths with cotton batting. Silk gauze is also used in the nitro-cellulose process after pre-filtering through fine meshed tinned metal gauze. It is impossible to use these filter media in the cupra-ammonium process, for they would be attacked by the solution. In the case of the cupra-ammonium process filter plates of very fine metal cloth and asbestos are used.

Air Bubble Removal.—The filtered solution contains a great many air bubbles which cling to the viscous mass with great tenacity. Since these would cause breaks of the filament in the spinning process, the solution must be carefully freed from them. By a period of long standing, however, they rise through the solution and ultimately disappear. This process is too slow and, therefore, the expediency of warming the solutions and subjecting them to reduced pressures is resorted to.

Ripening.—In most cases, the solution must be allowed to rest for a time after it is made in order to ripen; that is, to arrive in such condition that its coagulability for rapid thread formation is most favorable. This change in the solution, which is accompanied by an increase in viscosity, is no doubt due to the tendency of the dissolved molecules to grow into a more complex and stable state with time. The spinning operation brings about the reversed action in splitting up the molecules again. If the solution is allowed to stand too long a spontaneous decomposition takes place, which is readily apparent in the altered gelatinous form of the substance in the solution vessel.

However, not all solutions have the tendency toward molecular condensation. Some, especially those in which the solvent has the tendency to break up the molecule, become more fluid with time because the solvent has longer time to work on the complex material and works upon the dissolved colloid to such a point that the toughness in the original solution is entirely destroyed and it has become use-

less for spinning purposes. This, for instance, is the case with the cupra-ammonium solution of cellulose.

THE SPINNING PROCESS

The solution, prepared and ready for spinning is now subjected to the processes which convert it to a filament. Besides the correct chemical property of the solution it is of utmost importance to have a succession of mechanical contrivances which will produce a satisfactory thread. A good solution may produce a poor, weak and lusterless thread if the spinning mechanism is not properly designed. For continuous filament formation it is necessary that a sufficient mass of the solution be exuded from the spinneret. This is brought about by keeping the solution always under a constant pressure. To avoid the use of too small spinneret holes it is customary to have them a little larger than the desired filament diameter and then give the filament a slight stretch as it is formed, fixing the same in its stretched state.

Stretch Spinning Process.—The name of “stretch spinning” is given to the process wherein a filament is forced through spinneret holes of comparatively large diameter, say from .25 to .50 mm., and then subsequently elongating the filament and constricting its diameter by a very considerable stretch. It is important for the success of this process that the filament should, in its stretching stage, be passing through a very mildly effective coagulating medium, which effects the filament structure gradually. After having been stretched sufficiently fine, the filament enters a more powerful fixation bath for its final coagulation, or if this is not feasible, then its rate of passage through the weaker bath must be less speedy, so that its time in the bath will be sufficient for the complete hardening of the thread.

It is obvious that considerable stretching of the thread

and the use of slowly working coagulating fluids means a slow rate of filament production. The smaller the spinneret opening, the less the filament need be stretched and, therefore, the more rapidly the filament can be coagulated, withdrawn and wound. This advantage, however, in arriving at a rapid production rate by the use of small spinneret holes has the disadvantage that one must use very high pressures in order to force the solution through, and must, as a consequence employ heavily constructed apparatus.

THEORY OF THE SPINNING PROCESS

Coagulation of the filament is brought about through the effect of a medium wherein the molecules of the solution, which up to now had been movable, are brought together and rendered immobile in a certain fixed position. One can picture this process as one in which the molecules clasp hands or seize each other and remain in this united contact. When this occurs, a contraction of the filament mass takes place.

If, for example, the cellulose content of the solution is 6 to 8 per cent it will become in the case of the coagulated, but still wet filament, about 15 to 20 per cent. Since the filament represents only a completely stiffened colloidal solution, it is to be expected that the properties of the original solution will be present in the filament also.

This enables us to understand the importance of the properties demanded of a good solution; namely, sufficient concentration and viscosity. The higher the concentration, that is, the more molecules there are in the solution, the firmer will be the structure of the finished filament. But if the concentration of the solution results in a certain tenacity due to molecular size, precautions must be taken to guard against the molecules in solution being disrupted too

far so that they still possess the property of ready cohesion. Again, when the solution is coagulated, if the molecules endeavor to interlock and cohere too strongly so that in this stage of stretching and spinning too much of the mechanical strain is imposed, the result will be a filament of poor quality in respect to elasticity and strength.

The Effect of the Coagulating Bath.—In order to insure the luster of the filament, it is important that the coagulation of the filament-forming mass should occur homogeneously throughout. Any condition which interferes with the transparency of the filament naturally lessens its luster. These dangers are less to be feared in the case of such solutions which merely represent a precipitation of previously dissolved cellulose compounds rather than in the case of those which, in their precipitation, require the actual elimination of some constituent of the molecule, and therefore involve some decided disturbance of the molecular structure. Above all, in case gases are liberated during this molecular transformation it is of serious detrimental effect to the filament. From the difficulties herein mentioned it is readily conceivable that the nature of the coagulating bath is of tremendous importance in the process.

THE FURTHER HANDLING AND PROCESSING OF THE FILAMENT

The coagulated threads gathered in some suitable manner and wound on spools, bobbins or reels still contain chemicals retained, either from the original solution or from the coagulating medium. These are removed by washing in fluids possessing the desired properties. If the constituent removed is costly, devices are arranged for its recovery. In the washing process a further hardening of the filament usually occurs. Having been freed from all impurities, the wet threads must be dried and subjected to the further

mechanical processing of twisting and reeling. The machines used for this purpose are practically the same as those used in the twisting and reeling of real silk, excepting in some particular details where they must be especially adapted to suit the peculiar characteristics of the various types of Rayon threads which they are obliged to handle.

APPARATUS OF GENERAL APPLICATION

In preparing the solution, for the most part no specially designed apparatus is needed. The usual standard machines such as digestion tanks, kiers, centrifuges, bleach cylinders such as are used in the pre-treatment of cotton; mixing machines for the solution of the cellulose and its compounds; filter presses for filtration, are very little different from those which we find in other similar industries, namely explosives, paper making and other chemical industries.

A more accurate classification of equipment for the making of Rayon would fall into the following three groups:

(1) Modified chemical equipment to meet the special requirements of the Rayon industry. Under this group we find:

- (a) Boiling kiers.
- (b) Bleaching apparatus.
- (c) Extractors.
- (d) Dryers.
- (e) Presses.
- (f) Shredders.
- (g) Mixers.
- (h) Agitators.
- (i) Filter presses.

(2) Special equipment which had to go through a complete state of development. Under this group we find:

- (a) Spinning machine, and its co-related devices such as the spinning or pressure pumps.
- (b) Spinnerets.

- (c) Bobbins or spools.
- (d) Centrifugal pot.
- (e) Washing devices.
- (f) Dryers.

(3) Modified textile equipment to meet the special requirements of the Rayon industry. Under this group we find:

- (a) Spoolers.
- (b) Twisters.
- (c) Reelers.
- (d) Washing devices.
- (e) Dryers.

As indicated in the beginning under this heading no specially designed apparatus is needed for the first group, as all the equipment is only an adaptation of machinery from the chemical field with some overlapping into the textile field. The development of the machinery in the second group was difficult, as nothing similar existed. The spinning machine soon developed need of both chemical and textile requirements in its design. The first machines called for much study until it was determined that the metals of which they were built must be such as to resist the attacks of the acid solutions and that they required accuracy of construction and control of co-related devices. The spinning machine is unique to the Rayon industry, and has for its sole purpose the production of threads or filaments from a solution. While it is a sturdy machine, its operations are delicate. It is designed to deliver a definite and unvarying quantity of solution per given period of time and convert it into a filament, which is then either piled into what looks like a cake in a high-speed revolving pot or wound on a bobbin. The spinning machines for the various processes are almost, without exception, alike, and many forms of apparatus could serve for all spinning methods, in process and detail.

The modern spinning machine consists primarily of the following co-related devices:

Pressure Pumps.—The solution is fed to the spinning machine from storage tanks after filtration, either with direct air pressure or, if very high pressure is required by means of hydraulic pumps, being forced out of the small spinneret openings under very high pressure. One of the most essential properties of a good thread is a uniform diameter. The diameter of the filament is determined by the percentage content of the solution, together with the speed with which it is pressed from the spinneret. This is dependent upon the viscosity of the solution and the degree of pressure.

The percentage composition of the solution is easily maintained at the same point. However, as previously mentioned, it is difficult to arrive at equal viscosities, so that varying pressures must be used with varying viscosities. This necessity for regulating pressure requires careful attention. Difficulties occur when the resistance of the piping changes. Candle filters, small individual filters inserted between the pressure pumps and the spinnerets must be frequently renewed and cleaned. Modern spinning pumps are of either the piston type, which was brought out in 1900 by an Englishman, Clayton, or gear pumps, which were brought out later. These pumps are very small and are designed to push forward at all times minute equal masses of solution at equal time intervals, independent of temperature, and in this way produce filaments or threads of equal size.

The most recent development of the piston pump in the United States has been made by the Wicaco Screw & Machine Works, Inc.* The Wicaco pump is of the multiple-piston type, the number of pistons varying from three to six. It is claimed that it is so constructed that all pulsations in delivery are eliminated and the pressure at the spinneret is

* Philadelphia, Pa.

constant, resulting in uniform deniers; also that they show a uniformity of denier, varying less than one-fifth of the usual tolerance. Under severe tests where very fine denier was required, they maintained an accuracy within one-seventh of the usual tolerance. The pump has a number of parts, whether gear or piston type, and is efficiently machined and fitted. All

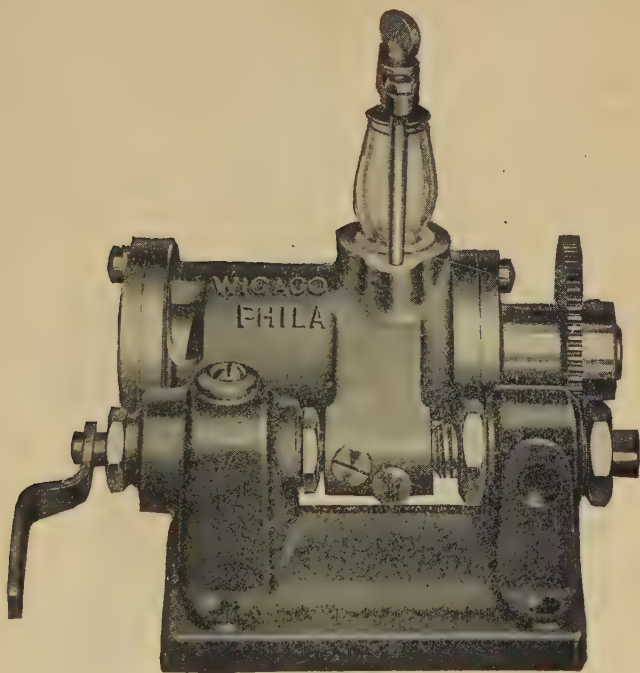


FIG. 38. Rayon Spinning Pump (Wicaco).

interior parts are fitted within .0002. Its construction permits its use within any style of bracket or frame. Or when it is desired to change the denier, an adjustment on the driving mechanism of the frame causes every pump on the frame to exert the same pressure behind each spinneret and thus to yield the same denier. In other words, the last pump on the

frame should produce as much Grade A filament as the pump nearest the beginning of the feed line.

In order to avoid the variations in the uniformity of the filament which are also caused by changes in the rate at which

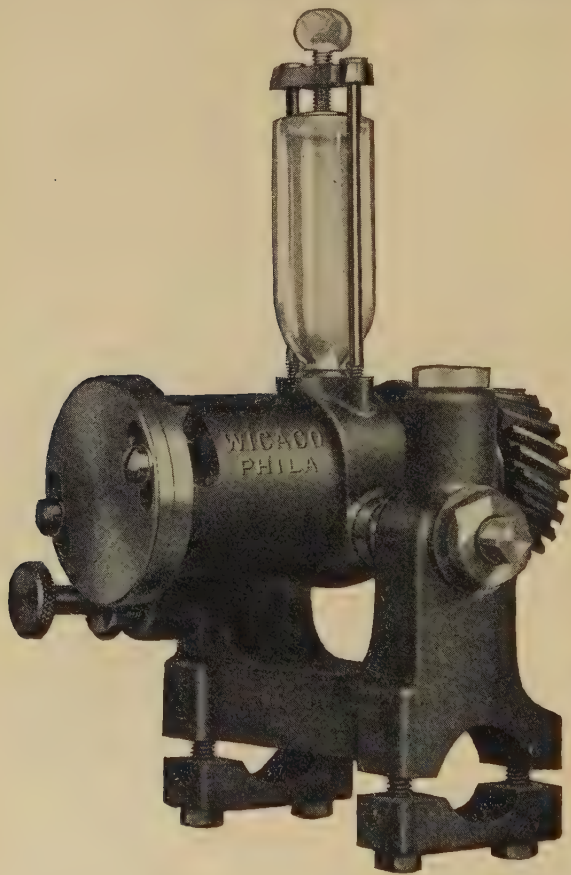


FIG. 39. Rayon Spinning Pump (Wicaco).

the solution is forced from the spinneret, as well as those which result from the speed of the gathering and winding devices, it is necessary to tie in the driving mechanism of the

pistons with the gathering and winding apparatus. Since a spinning pump must be connected with each spinneret, this means a distinct increase in the cost of the equipment used, and has a decided tendency to complicate the entire spinning process.

SPINNERETS

The most vital part of the spinning machine consists of the spinneret from which the solution exudes to form the filaments.

Most mechanical devices have been brought to their present-day perfection by the processes of evolution and it is interesting to compare the first crude beginnings, based upon a principle not clearly understood, perhaps, with the efficient machine of today.

The spinneret by means of which Rayon filaments are formed, seems to be an exception to the all but universal rule. Minerva-like, it came into being fully armed for its task. Modern metallurgical science and modern precise methods have refined it, but essentially it has had the same general form from the beginning and it is not hard to find the reason. In his inventions, man has always looked to Nature for his inspiration; he has sought to copy her forms and her devices. His first dwellings were circular, his boats and ships partly followed the lines of a swimming bird, his first idea of a flying machine visualized flapping wings. He has had to alter, sometimes to discard, his model completely, but with the spinneret this was not so, because he found the method by which the silk worm produces silk to be the one possible way to make such fibres.

It remained for him but to devise an instrument perforated with holes sufficiently minute and to find a solution which could be forced through them and which, upon drying, would resemble true silk filaments. The great strides made in spin-

neret manufacture are therefore not dramatic nor even clearly traceable, as are those of engine design or architecture, but they are none the less real. The perfection of the precious metal spinneret of the present day is due to the consummate skill of the modern metallurgist in isolating, purifying and alloying metals and to the almost uncanny precision of modern machinery.

The spinnerets are used either in the form of single spinnerets, that is, each spinneret having a single opening, or in the form of the so-called Brausen spinneret, which has a group of openings. The glass spinneret of the single-hole type is usually adapted for the nitro-cellulose process. The multi-hole glass type is often used in the cupra-ammonium process. Glass, while used to some extent and having the advantage of being cheap and at the same time resistant to the chemical agents with which it comes in contact, is gradually being eliminated in favor of the precious-metal spinneret. In this country the only large user of glass spinnerets is the Tubize Company. While spinnerets of glass are still used, the nature of the material is such that perfect accuracy of the small holes cannot be attained. In actuality, they are capillary tubes and no matter what the skill of the glass blower may be, some variation will always exist between the diameters of the orifices.

The glass spinneret of the present day is a great advance over those made a few years ago. In fact, the spinneret making was an important step in the proper production of the viscous thread, and many obstacles had to be overcome before the modern spinneret was produced. Glass spinnerets are now produced with 66 holes, each hole being .0035 of an inch in diameter. Others are made with eighteen or more apertures of the diameter required.

Metal spinnerets, particularly precious metal, are made with the precision possible only with machined metal. Spe-

cialized mechanical equipment has been designed which produces spinnerets of precious metal with holes as small as .002 inch and numbering as many as 1000 in one cup. These holes are so accurately tooled that there is no detectable variation and tiny as they are, their walls appear as polished surfaces under the microscope. Platinum-gold and palladium-gold are the alloys most used and these are perfectly immune to any chemical action from the solutions used in Rayon making. The spinnerets are not subject to breakage and when their life of usefulness is over, they may be sold for the value of the precious metals which they contain.

The Brausen spinnerets are usually made in several metals and alloys, while base metal spinnerets are used successfully in the acetate process; for the Viscose process the platinum-gold alloy proved satisfactory. Spinnerets containing 70 per cent gold and 30 per cent platinum are popular in the United States while in Europe the percentage of platinum in a large number runs as low as 10 per cent, with 90 per cent gold. Both Europe and the United States use a spinneret made with an alloy of 20 per cent platinum and 80 per cent gold. One of the new innovations in spinneret alloys, which has proven equally adaptable with the platinum-gold alloy, is the combination of 80 per cent gold and 20 per cent palladium. Palladium is of the group of platinum metals. This alloy is acid-resisting and of the same tensile strength and hardness as the platinum and gold alloys; and further has the advantage of being cheaper and lighter in weight than the platinum-alloy spinnerets. Figure 40 shows the type of spinneret commonly used in the Viscose process.

While rigid specifications of accuracy are required for glass spinnerets the metal-types require no less attention in their making. The fine apertures must be exact and true, with edges that cannot be rough. The number and diameter of holes vary with the requirements. The usual number of holes

is twenty or forty-four although sixteen, eighteen, twenty-four, thirty-six, forty-two, sixty-six, eighty, one hundred and two hundred-hole spinnerets have been used. The diameter of hole most used is .004 and .0045 of an inch.

The Brausen or metal spinneret is constructed in the form of a small cap or hat, with the fine apertures or holes in the top. The length of the hole does not entirely depend on the diameter of the hole. The denier of a filament depends on the pump pressure regulation, condition of the spinning bath, take-up speed and other controlling factors, so that it is possible to draw a wide variety of denier filament from a spinneret with hole diameters of .0045 of an inch. The metal spinneret has this advantage, that the filaments without

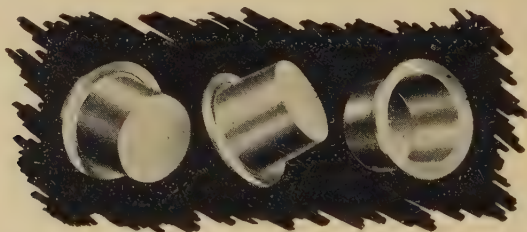


FIG. 40. Spinnerets—Metal Alloy. (Courtesy of Baker & Co., Inc.)

much further bringing together are united into a thread almost as soon as they come out of the spinneret.

The spinneret of platinum alloy has this advantage: It can be cleaned by heating to a red heat and furthermore it is not easily broken, as is the case with glass spinnerets. On the other hand, the platinum alloy spinnerets have the disadvantage of being very expensive. Moreover, if a single hole in the spinneret becomes stopped, it must be removed from the goose neck and replaced with another, which interrupts production at this point. The cleaning of the spinneret after usage is important as methods may be used which are injurious, resulting in distortion and enlargement of the holes.

One of the methods considered good is to remove the spinneret from the spinning machine and immerse it in water, which will prevent the setting of the solution on the surface or holes of the spinneret. Boiling the spinnerets in a diluted solution of hydrochloric acid for about fifteen minutes is the next step, after which they should be washed in clean water and dried, when they can be used again. There are various other methods used to clean the spinnerets, among which is the zinc-chloride method, in which the spinnerets are immersed in a solution of zinc chloride and then washed in a solution containing 10 per cent hydrochloric acid, 40 per cent sulphuric acid and 50 per cent distilled water.

There is no salvage value for glass spinnerets. The metal spinnerets can be returned to the manufacturer, who will pay for the salvage value of the metal in the spinneret. Aside from the glass and metal spinnerets above described other attempts to manufacture spinnerets from porcelain, china and other materials have not met with success.

Arrangements of Spinnerets.—The various spinneret arrangements are largely protected by patents; many have their particular advantages for the special process in which they are used. In fact, one of the problems at the beginning was that of securing the spinneret. Difficulties in this regard were encountered with both the glass and metal spinneret. Today, however, the making and its application is practically standardized, with such refinements continually added to bring about accuracy and reduced cost of manufacture.

The evolution of the spinneret is shown to some extent by a study of some of the patents* which have been issued in the United States and in Europe and which are briefly described herewith:

The problem of replacing spinnerets is disclosed in U. S. patent No. 713,360 Nov. 11, 1902 (J. Stoerck, *et al.*). [Fig. 41A.]

* American Silk Journal.

This idea consisted of providing in place of the long capillary tubes special filament-forming cocks. The viscous liquid was passed into a long supply pipe which was provided with a series of these cocks. Each of these was composed of a cylindrical cap which was fitted to the upper conical end of the cock. The upper part of the cylindrical cap was provided with a capillary hole of about one four-thousandth of an inch, drilled by very fine instruments. The cocks were nothing more than compact little jets controlled by a tiny valve.

It soon became apparent that a material was needed which could withstand the ravages of the chemicals used in the process. Glass was a common material. Platinum, long known as a universal resisting agent, was then employed to a great extent—and still is today.

Again, it began to be seen that an improvement could be made in the apparatus used. Why have a number of pipes with a series of jets? Why not use a single pipe covered at one end with a plate punctured by numerous minute perforations?

In U. S. patent No. 858,648 (July 2, 1907—Charles A. Ernst) [Fig. 41B] several changes along this line were suggested. This improvement proposed to dispense with the expensive platinum spinneret and utilize, instead, one made of hard rubber or some other material which was sufficiently strong to withstand the requisite high pressure and at the same time be chemically neutral or resistant to viscose. In using hard rubber it was obvious that the cost would be reduced considerably. The sheets of hard rubber could be made thin enough to enable minute perforations of uniform size to be drilled therein.

A feed pipe was therefore provided which had a cap at its end. Within the cap were placed two cuplike plates. The end plate of hard rubber was made up of narrowing circles of drilled or punched apertures. A little distance from it—and within the cap—was a similar cup with smaller perforations. This was the strainer which served to remove foreign matter in the viscose to prevent clogging of the spinneret.

From this point onward improvements in the construction of the spinneret developed rapidly. *Uniform thickness of filament was the keynote of all research in the Rayon industry.*

A noteworthy departure from the orthodox method of drilling these tiny apertures directly into the bottom of the spinneret

cup was the process described in U. S. Patent No. 1,337,258—(Apr. 20, 1920—O. Ohlson). The body of the spinneret was made of metal. Molybdenum, Monel metal, platinum, were some that could be used. The bottom was provided with relatively large perforations. They were counter-bored to form a shoulder between the inner and outer surfaces of the end wall of the spinneret. In each of these openings there was secured an orifice plate which was pressed tightly into the counterbore and against the shoulder. The orifice plate was provided with a minute perforation made by drilling or punching. There were 16 such orifices on each cup. They were extremely minute, scarcely visible to the naked eye. [Fig. 34C.]

Using different materials in the spinneret structure, of course, produced different results. Some of the many materials that have been used are:—Bakelite, metals such as Molybdenum, platinum, gold and silver, Monel metal (copper and nickel alloy), diamond, glass and porcelain. Each material presented a different obstacle. Platinum, because it is so valuable, had to be cut in extremely thin sheets. When too thin the pressure of the material which is squirted through the nozzle caused the portion in which the aperture was formed to be bulged outward—thus deforming the opening. This was especially the case when a slot for squirting strips was used.

Under the above circumstances it was suggested in U. S. Patent No. 1,366,166 (Jan. 18, 1921—J. E. Crizzal) that Monel metal be used in place of platinum for slotted squirting nozzles. The making of a slotted spinneret presented an interesting example of ingenuity. The body part of the nozzle consisted of a tubular portion within an inward flange at one end a little distance from the end. A disk, divided diametrically into two parts, was provided and in the straight side of one of these half disks, a slot of the required size was formed by cutting into the half disk from the straight side. The slot was then shaped and polished and formed one side and the two ends of the slot in the finished nozzle. The remainder of the straight side of the half disk and also the straight side of the companion half disk were made to fit against each other and that part of the straight side of the second half disk opposite the slot in the first named half disk, when the two half disks were placed together, constituted the second side of the slot. The disk was then riveted into

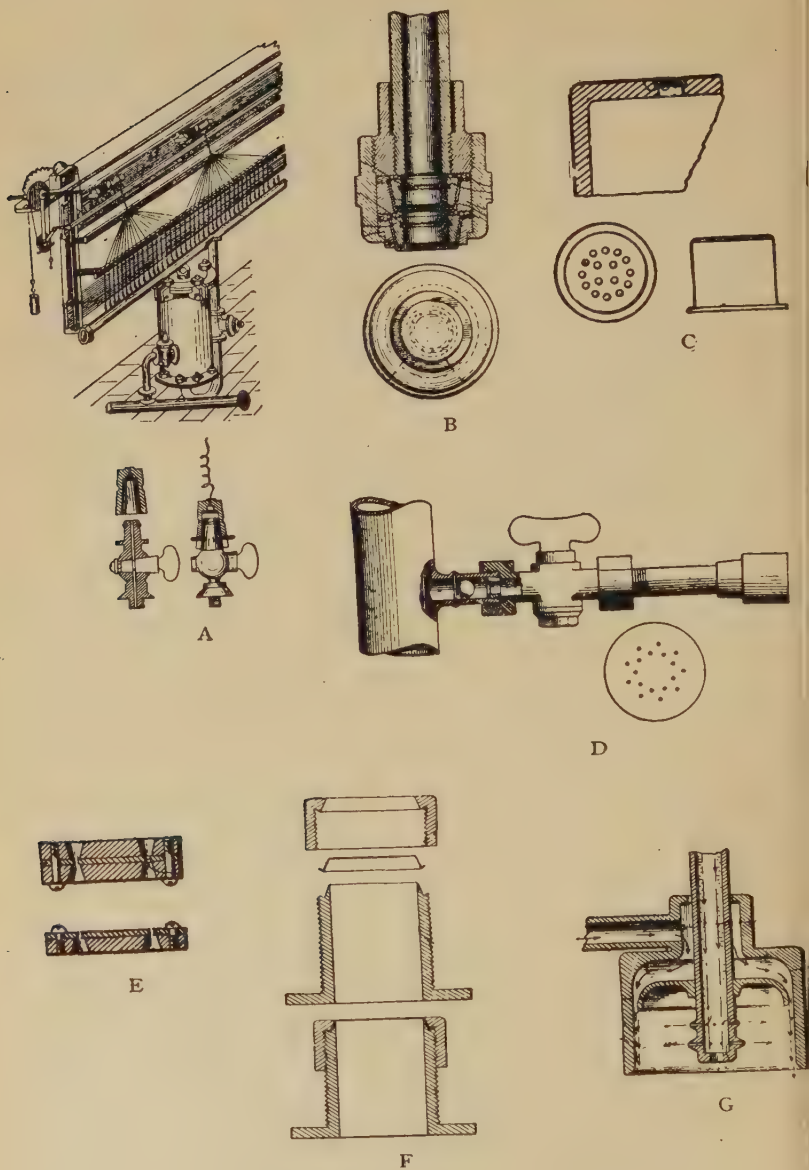


FIG. 41. Evolution of the Rayon Spinneret.

place on the inner flange of the body nozzle and a strip squirter was ready for action.

Platinum alloy tubes may be made in a manner different from drilling rivets of the alloy. Tubes of any required bore and of highly perfect formation may be made by coaxially perforating a machined solid cylinder of platinum wire. A core of relatively soluble metal (as silver, copper or nickel) is accurately fitted into the perforation. The mass is thereafter drawn in the fashion usual for wire manufacture—through dies of gradually narrowing dimensions. A peculiar and fortunate thing occurs at this point. It is found that no matter how fine the wire is drawn, the two dissimilar metals act as if one metal only were being drawn. Therefore—by knowing the external diameter of the wire—we can tell what the precise diameter of the core is.

The wire is then cut by machine into any equal short lengths. It is treated chemically so as to dissolve out the core and constitute the tube. The end of the tube is machined so clearly that under the microscope it appears truly circular.

There is no limit in practice in point of minuteness of apertures to which the composite wire can be drawn. It is found that if the aperture be of the order of magnitude only of 5/10,000 of an inch, the extraction by chemical means of the soluble core has been found to be quite easily effected. The accuracy of these apertures is well within the thousandth of an inch. A recent foreign development is the production of hollow filament. This form can be secured by the above method of building up various cores of soluble and non-soluble metals, with the soluble core hollowed out.

Returning again to spinnerets that squirt circular filaments—we see an unusual form in U. S. Patent No. 1,405,132 (Jan. 31, 1922—F. Heidelberg *et al.*) [Fig. 41D.] The solution pipe carries a series of upright equally spaced extensions in a manner reminiscent of the early Chardonnet apparatus. The outer end of the extension is provided with a head or spinneret of hard rubber provided in its outer end with a series of minute apertures in which short glass plugs are inserted. Through each of the plugs there is a capillary opening.

In U. S. Patent No. 1,492,594 (May 6, 1924—C. Dreyfuss, *et al.*) [Fig. 41E] it was found that far better results were obtained for any pressure or spinning solution by securing a very

thin sheet of metal containing the spinning holes, drilled of size and number necessary to give the desired filaments, between two reinforcing sheets. The upper and lower reinforcing plates are provided with tapered openings corresponding to the openings in the clamped plate. The three elements are then riveted together.

A very simple type of "silk worm" was devised by J. E. Crizzal in U. S. Patent No. 1,593,442—(July 20, 1926) [Fig. 41F]. Wire gauze made of platinum, phosphor-bronze or Monel metal are pressed between flat surfaces under pressure to flatten the surface. This enables the spinning to take place more easily than is the case if such pressure had not been applied. The apertures between the wires may be left in that condition, or they may be altered in shape. The gauze is placed over a hollow tubular member and then secured into place by a cap member.

A recent British patent discloses some interesting side-lights on the manufacture of the spinneret (BP 253,209—C. L. Walker). One of the great drawbacks to the use of plates of platinum is the danger of theft of these plates in a spinning factory and the cost of measures of precaution to prevent such theft. The outlay of capital is also considerable. To overcome this obstacle, nozzles, the bodies of which are made of molybdenum, may have alloy tubes fitted in perforations in the bottom thereof. The metal may be platinum having 10 per cent of iridium. The tubes are made by placing rivets in the perforations and compressing them while being expanded into place by the riveting machine.

Heretofore, only stationary spinnerets have been described. Inventive ingenuity soon devised a movable squirter [Fig. 41G]. In U. S. Patent No. 1,500,931—(J. J. Hooper—July 8, 1924)—is described a centrifugal spinneret.

A spindle, through whose central passage passes the viscose solution, is provided. The lower end of the spindle has minute lateral passages through it, which allows the viscose material to be discharged by the rotating setting solution and are delivered in a wound condition.

The setting or coagulating solution is delivered to a deflector plate which is attached to the spindle. The setting solution is thrown laterally and rotated and takes the form of a rotating column which surrounds the apertures in the spindle. The fila-

ments ejected through the rotating apertures come in contact with the rotating setting solution and are delivered in a wound condition.

What the future has in store for further spinneret development only a prophet can foretell. The trend is persistently toward simplicity, uniformity and accuracy.

GATHERING THE SPUN THREADS

By Bobbin or Spools.—The threads of Rayon are withdrawn from the spinneret at a uniform rate and are gathered by means of cylindrical bodies turning at a uniform rate of speed such as cylinders, spools, bobbins or reels. The gathering of the thread in this manner is done as regularly and as systematically as possible, and must be done in such a way that the threads can be handled further in their processing without damage, and so that no tangling of the thread results. The winding devices, at present in use, are of various diameters and can be made of a great variety of materials. The spools are largely of glass, metal, or paper. Reels are for the most part made of wood or metal. The tendency has been toward perforated spools and corrugated spools. The method of winding most preferred is that of cross-winding, in which the threads are laid at an angle to the direction of winding as the bobbin guide passes toward one side, and this angle of winding is reversed when passing to the other side. This method also simplifies the subsequent handling of the threads.

By Centrifugal Pot.—Another way of gathering the thread after it is withdrawn from the spinneret is by the use of the centrifugal pot, which unlike the bobbin combines in one operation the twisting of the many spinneret threads into a yarn and the winding or depositing the wet yarn on the inside of the rapidly revolving pot. This spinning pot was brought out in England by Topham in the year 1902. This pot revolves at a speed of about six thousand revolutions per minute. It must

be well balanced and made to resist the acids of the bath. It has the advantage over the bobbin because it dispenses with the washing and drying processes previous to twisting. This interesting invention is more fully described in Chapter XI on the Viscose process.

WASHING OF RAYON ON THE SPOOL

In nearly all processes with the possible exception of the Acetate, Rayon must be washed after the spooling in order to remove the chemicals still contained in the thread, it being desired to accomplish this in the quickest possible way and with the application of the least possible quantity of washing material. The latter is of especial importance if the matter of chemical recovery is to be considered.

DRYING

The drying of Rayon, after the spinning operation, is carried out through evaporation of the moisture from the yarn.

Drying is usually accomplished by rotating the skeins or spools slowly in an atmosphere properly conditioned as to temperature. Constant rotation avoids the difficulty of having all of the washed water drip off at the bottom with the resulting inequality of drying which, of course, would have a serious effect on the uniformity of strength and dyeing properties of the yarn.

There are two evaporating processes after the spinning operation:

1. The first drying process is usually carried out under tension. It is done by having the skeins or hanks placed in specially designed wheel trucks combining into a "stretcher frame." This "stretcher frame" is so designed that after the

hanks are placed thereon in a loose state by adjustment of one of the rails of the frame the proper stretch is imparted to the skeins. These frames are usually made of either aluminum, copper or manganese. They must be strong but of light construction and such as to avoid contamination of the yarn.

2. The second process of drying is by the use of the chamber wherein heating coils are properly distributed and also where the air is kept in motion by propeller fans and exhausted by wheel fans, when saturated by moisture.

Until recently drying rooms were used for this purpose but they were not economical as to heat and proper distribution of temperature, but the latest type of drying machines possess all the advantages without being wasteful or inconvenient. To carry out the drying process it would take, after eliminating the initial water from the skeins through the "stretcher frames," about six chambers which fully charged would give the following Fahrenheit temperature readings:

<i>Dry End</i>					<i>Wet End</i>
<i>First</i>	<i>Second</i>	<i>Third</i>	<i>Fourth</i>	<i>Fifth</i>	<i>Sixth</i>
<i>Chamber</i>	<i>Chamber</i>	<i>Chamber</i>	<i>Chamber</i>	<i>Chamber</i>	<i>Chamber</i>
110°	140°	150°	160°	140°	120°

When the skeins are first put on the "stretcher frames" they contain almost six times their own weight in water and during this time they may be subjected to any temperature short of boiling point without any danger, but when the Rayon is dried, or almost dried, it is usually subjected to 110° heat.

The capacity of a well-designed drying machine for evaporation of moisture and a six-chamber arrangement as above indicated is about 800 pounds of water per hour, of which a portion of the moisture would be forced out of the skein by the application of the tension in the "stretcher frame" and about 500 per cent of the moisture would be evaporated in the drying machine.

The new type of chamber drying machines are built, tunnel-like, with doors both in front and back so as to permit the "stretcher frames" carrying the hanks to enter at one end of the chamber and be taken out at the other end, permitting of continuous operation. These tunnel chamber machines, that is, chamber drying machines with two openings, are designed wide enough to accommodate three or four frames in a row.

It is important that the heated air currents first attack the bottoms of the skeins, as more perfect evaporation will be obtained because the skeins due to their vertical position will be loaded with more moisture at the bottom; hence, it is essential that the heated air currents be brought into contact with that part of the skein which is more loaded with moisture. Due to the presence of sulphur the yarn is harsh after drying in the heating chamber even though the skeins are washed in a cold water bath prior to their being put under tension on the "stretcher frames." The amount of sulphur which remains in the skeins after the cold water bath which takes place prior to their being put under tension on the "stretcher frames" causes the threads to stick to each other momentarily, but they can be separated when the first desulphurising process, which takes place between the "stretcher frame" drying and chamber drying, is effected at a temperature of about 150° F. Further in the process occurs the second desulphurising step, also acidifying, bleaching and washing where drying is carried out through hydro-extraction by centrifugal velocity.

These hydro-extractor drying devices consist of a perforated drum mounted on a vertical shaft and surrounded by a steel outer cage with the top of the cage opened for accessibility. After the wet material is placed around the inner surface of the cage, the latter is subjected to high speed generating a high centrifugal force. The moisture in the

Rayon is, therefore, forced to escape through the perforations of the cage and within the short time of about five minutes the hanks are left uniformly dry, the moisture not exceeding 4 per cent of the weight of the material taken out from the hydro-extractor.

The power to operate a 36-inch diameter hydro-extractor, preferably by electrical motor, does not exceed 6 H.P. for starting and about $2\frac{1}{2}$ H.P. for running. A 72-inch extractor will require about 20 H.P. for starting and about 10 H.P. for running.

After most of the moisture is taken out from the Rayon hanks through centrifugal extraction the "loose" drying follows which is a very delicate drying operation. After taking the hanks of Rayon out of the hydro-extractors, they are laid down upon a table and straightened. Then they are placed or hung loosely on poles either of metal or wood. Following this, these poles are either sent through a tunnel machine to perform the operation of drying, cooling and conditioning; or placed on trucks and wheeled into a drying room; or they are hung in cells of a chamber drying machine.

All through the process of drying, care must be taken not to color the Rayon yarn. It is essential therefore, that during the last operations of loose drying of the hanks, the air be filtered in order that any of its impurities be washed off. The air which is used throughout all these final stages of drying and moisture conditioning of the yarn, should be washed through special filters. This is the more necessary when Rayon plants are built in cities, or close to cities, where there are many other manufacturing plants. The tendency of selecting sites away from cities, in valleys, where the air is naturally clean and pure is due largely to this consideration. It aids both the processing of the Rayon yarn and keeps the people, who produce it, happy and contented.

ABBREVIATED PROCESSES

Many abbreviated or continuous processes have been tried, aiming at the production of a merchantable fiber in one continuous uninterrupted operation from the spinneret to the grading or inspection department. None of these continuous or short-cut processes have up to now been successful, though it is to be expected that there will arise complex machinery designed for controlling the movement of the tender threads throughout their passage, with intricacy of mechanism and a correlation of movement. The greatest advance in Rayon production will come from this apparently difficult development, irrespective of what the original cost or maintenance of such machinery might be.

MODIFIED TEXTILE EQUIPMENT

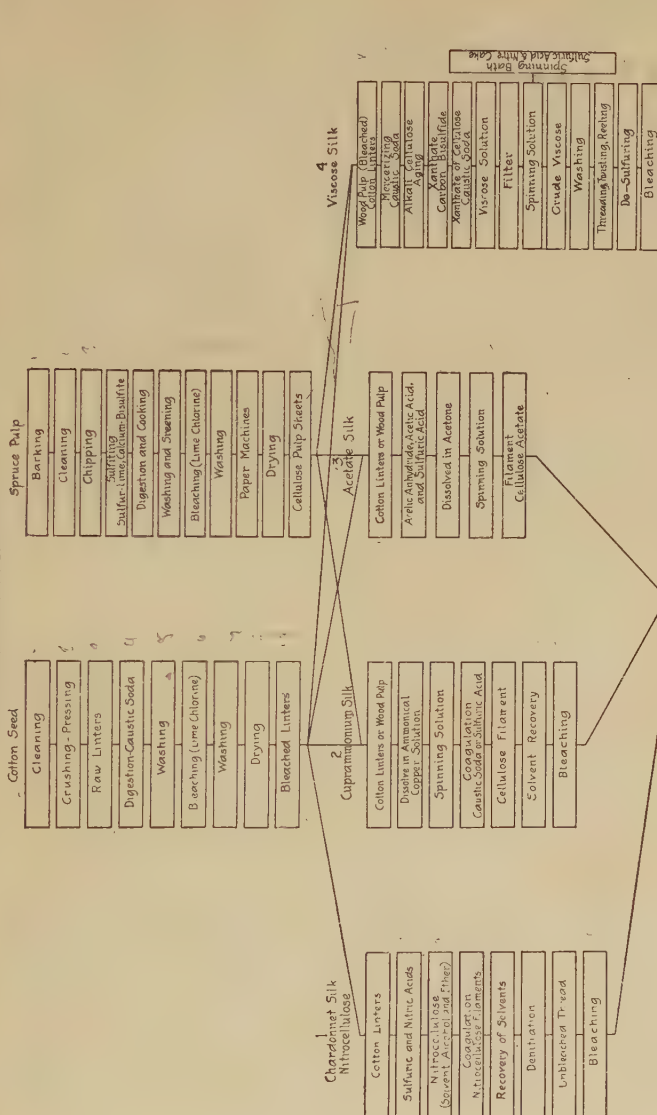
The modified textile equipment found in the third group is represented by textile equipment remodeled to meet the requirements of the Rayon industry.

Spooling.—For the most part, after the Rayon has been washed, it is wound on smaller spools from which it is then given the twisting operation.

The Twisting of Rayon.—In order to improve the strength of the open and parallel lying Rayon threads, and to make it easier to handle subsequently, they are given a certain amount of twisting. For this purpose standard or modified textile twisting machines are used. Twisting of the yarn through the use of twisting machines is essential where the bobbin system of spinning is employed. In the case of the centrifugal pot system the twist is made during the process of spinning. In the process of making cellulose-acetate silk, such as the brand known as "Celanese," the thread is spun dry in warm air, instead of coagulating in a chemical solution,

RAYON PROCESS—FLOW SHEET

RAW MATERIALS



M. H. AVRAM & COMPANY
 85 BROAD STREET
 NEW YORK
 NOVEMBER, 1926

CHART 27. Flow Sheet of the Four Rayon Processes.

as is the case with the other processes. In the acetate case, however, the thread is twisted while being loaded at high speed on a cone of paper or other material. These cones are then removed from the spinning machine and the acetate silk on them transposed onto a spool, after which the thread is ready for commercial processing.

The Reeling of Rayon.—After the Rayon has been twisted it is run on reels in the familiar types of reeling machines. From the reels, the Rayon is removed in the form of hanks. When the hanks are removed from the reels they are tied in three or four places in order to prevent the subsequent tangling of the threads. The Rayon is then subjected to such special processes as may be required, depending upon the general method of production. For example, in the Chardonnet, the next steps would be denitration, bleaching, etc. These intermediate processes will be described in greater detail with drawings and cuts of apparatus shown when each particular process is discussed in the chapters which follow.

The subject of the fundamental principles of Rayon making involves the four processes now exploited commercially, the Nitro-cellulose, the Cupra-ammonium, the Acetate and Viscose processes. Even though improvements and modifications are constantly being added to each of the processes there are no others in the field. Although scientists in the art are working on new discoveries there is yet no revolutionary process in sight.

The Chart 27 has been prepared to show the succeeding steps necessary to carry out commercially each separate process, starting from the raw material to the commercial Rayon yarn.

CHAPTER IX

RAYON ENGINEERING PROBLEMS

ENGINEERING, in the sense of the established practice for mass production, was applied to the Rayon Industry only recently—after the advent of large capital influence into this field. In the initial stages all the engineering was of the laboratory type resulting mainly from the experience of the scientific experimenters, such as Count Chardonnet and others, so that the first commercial plants had the semblance of large experimental units, where the entire equipment was designed and controlled after the conception of these scientists.

Until recent years the principles of general engineering practice could not apply as a whole to this industry since many of the chemical phases of the processes were the result of discovery through sheer effort over years of work and the numerous details of the process behavior were unknown, as has been the case for a long time with industries such as paper, steel and cotton. In recent years broad principles of Rayon plant engineering have been established so that all the divisions of a Rayon plant indicate a correlative sequence leaning toward standardization. All Rayon plant engineers continuously aim for greater advancement in plant design.

It is interesting to note that most of the American companies producing Rayon have associated themselves with old established Rayon-making companies abroad from which they obtained experience and a trained personnel of technical men and operators. The Viscose Company, which is practically owned by Samuel Courtauld & Sons, Ltd., of England, was

organized in 1910, and the first plant built and operated by its English staff. The Tubize Artificial Silk Company of America came into existence by an arrangement with the Fabrique de Soie Artificielle de Tubize of Belgium. The Du Pont Rayon Company arranged operating relations with Syndicat des Textiles Artificiels of France, and the Industrial Rayon Corporation, the result of a number of reorganized companies reached the stage of successful production when the Italian company Snia took a hand in its affairs.

The above are the four principal American companies which had to pay handsome tribute for getting service and cooperation from the European Rayon companies. The chances of failure, however, were reduced, and the result is represented by very large earnings, a large part of which still go abroad. Toll, however, need not stand in the way of new companies entering this field of industry, for while the American is willing to pay well for being shown, he soon learns to surpass his European brother in engineering practice and production without having to pay a perpetual tribute.

Engineering as applied to the design and construction of Rayon plants can be broadly divided in:

- (a) Engineering of plant standards.
- (b) Engineering of process details.

In the first instance the principal factors that have to be considered are:

1. Selection of site for plant location.
2. Types and design of building necessary for any of the four known processes, to wit: Viscose, nitro-cellulose, cupra-ammonium and cellulose acetate.
3. Considerations as to water requirements.
4. Considerations as to air conditioning or temperature and humidity regulation.
5. Considerations as to power and steam.

6. Considerations as to research laboratories and development.
7. Considerations as to transportation—yard traffic regulation.
8. Labor and living conditions.

I. *Regarding the selection of site: The selection of a site suitable for a new Rayon project must meet approximately the following specifications:*

(a) The topography of site must be practically level, of an area of not less than 50 acres.

(b) The water supply must have a minimum flow of not less than 40 to 60 million gallons daily. It must be clean and soft and comply with the rigid specifications of water given under the chapter "Raw Materials."

(c) The freight rate on coal not to exceed \$1.50 from the mines.

(d) The altitude should be about 1,000 feet above sea level.

(e) In order to dispose of wastes there should be a river or other body of water nearby into which these wastes may flow, which has a drainage area, above the plant sites, of 5,000 or more square miles.

(f) Railroad connections should be sufficient and at least one railroad must be right within the site.

(g) The labor supply must be such as not to interfere with the enlargement of production. In other words, there should not be a large number of other industries which would compete for labor. The plant should be located close to a city of not less than 7,500 people.

From the above it must be noted that any new site must compare favorably in every way with those of operating plants which are favored as to location and operating conditions.

2. *Regarding types and design of buildings:*

The buildings are approximately of one type for the four different processes, excepting that in the case of the buildings for cellulose-acetate silk there are two separate structures in one of which the cellulose acetate is manufactured while in the other the cellulose acetate is converted into acetate silk. These buildings are placed some distance apart so that the fumes and gases in the manufacture of the cellulose acetate would not be injurious in the process of making the acetate silk.

As a whole, like all industrial plants, one of the important features in designing a building for the production of Rayon is proper routing of the raw materials from the beginning to the end of the process until a high quality Rayon yarn is produced, packed and made ready for shipment. The planning of the building to permit of proper routing has therefore a great influence on the ultimate cost of the finished product.

In order that economical production be obtained, the total amount of Rayon for which the plant is designed should be produced daily without interruption irrespective of the shipments made from day to day. There are periods when shipments are not made, and, therefore, adequate storage space for both the raw materials and the finished product should be provided. Therefore, the storage division must be so designed that it would take up the surplus of all finished Rayon yarn during the period when the demand is decreased. On this basis one can obtain a balance of plant production without regard to any particular season. In the same manner excess storage space must be built so as to permit of storage of a large amount of raw materials which come in, in bulk or in liquid form.

There are two distinct sections to a Rayon building. One is for the chemical and the other is for the textile end of the process. In the first section the solution is prepared, and in

the other it is coagulated into filaments and treated from stage to stage until reeled into skeins and then inspected and packed for shipment. The largest building is the one where the final textile operations take place. This represents the main building with a very large room at one end, where are located the tanks containing ripe Viscose solution ready to be spun into Rayon yarn. These tanks are installed either on the same floor with the spinning machines or in a cellar beneath the spinning floor, and in some cases over the spinning department, depending upon the process used.

At the other end or throughout the balance of this large room is installed the reeling, washing and drying sections. Towards the end of this room is installed the bleaching, washing, drying, storing and packing the finished yarn for shipment. In some cases the yarn is processed and shipped on bobbins, cones or spools.

The chemical building, particularly in the Viscose process, is separate from the main textile room or building. It must be one, two, three or more stories high to permit the processing of the raw materials step by step from the top floor to the bottom of the chemical building.

The main or textile building is usually designed and built with a roof known as the sawtooth skylight roof. In order that maximum light be obtained without shadows or glare, these skylights should face north. It has been the standard practice to build these large one-story sawtooth skylight roof buildings with a large number of columns throughout the building. Recently, however, sawtooth construction buildings have been built for a number of Rayon companies through a method of design which make it possible to build sawtooth roofs 100-foot span in one direction and of unlimited length in the other direction without any posts. This permits of great flexibility of interior arrangement of machinery with a new plant or where it is necessary to change the process and

machines after the plant is in operation for some time. Such a span also permits of the proper system of ventilation which is necessary and essential in the Rayon industry. It permits the air feeder ducts and the distribution ducts to be placed above the bottom cord of the trusses where they are in the most advantageous location and where they obstruct none of the light from the skylight.

A Rayon building is usually built in a number of small units in order that each unit has its own supervision and control.

There is considerable detail in connection with the design of a Rayon building and considerable time should be given to all the phases involved before starting the building program.

3. *Consideration as to water requirements:*

In the selection of a site the quality of the water is of paramount importance and, therefore, due to large quantities of water required, it is essential that the river above the plant location be investigated to its source to determine that no sewage or waste production from other plants will contaminate the water supply. Irrespective of all the care and study that is given in the selection of the water supply, which in a measure determines the location of the plant site, the quality of water, no matter how pure and soft it might be in its natural state, must be brought to the highest point of purity by the installation of a filtering plant with the necessary pumping plant and storage facilities for large bodies of water, where the water is soft in its natural river state the operation of the filter plant is relatively simple. A river from which water is available, rather than a lake or artesian wells, is of advantage, as it will help in disposing of the chemical wastes and by-products which are discharged with the same water which entered the Rayon plant. Were such a plant not located

close to a river an expense would be necessary in order to purify the wastes discharged from the plant, or a pipe line system, sometimes costly and prohibitive, would be necessary in order to convey these wastes into running waters. For purity of water it is advisable to use artesian well water where it can be obtained in sufficient quantities. Even if artesian well water is provided, it is equally essential to have the river nearby for waste discharges.

In connection with water it is of primary importance that it should not contain any trace of iron when used in the process of Rayon production. For the purification, however, of cotton linters and the sulphite pulp, the specifications recommended are that the iron content shall not exceed .022 per cent. Whenever any iron content is found in the analysis of the water, purification plants to eliminate this iron must be installed.

The methods of purification divide themselves into two groups, those which might be called natural (that is, they are brought about adventitiously by the forces of nature) and artificial methods, those brought about with forethought and intent by the hand of man. The natural forces active in the purification of surface waters are:

Sedimentation: Whenever the velocity of surface water is checked sedimentation takes place. It is obvious that the amount of sedimentation will depend on the initial load and will vary from season to season with the volume of flow.

Sunlight is also an active natural purifying agent. It bleaches out color and assists in the removal of bacterial growths.

Aeration is that process whereby the waters absorb air. With the absorption of air the oxygen thereof destroys organic matter, changing it to CO_2 . Some mineral compounds may be oxidized to a state of insolubility, in which case they are removed by precipitation.

Precipitation is also brought about by other means such

as loss of dissolved gases (especially CO_2), which keep and holds some solids in solution. Precipitation is also brought about by contact with other waters containing such dissolved substances as would react and form insoluble compounds.

Filtration: Natural filtration through soil and sub-soil is a very effective purifying agent, especially if these are sand, gravel or porous stone.

Action of the "Plankton": The "plankton" is the teeming vegetable and animal life which is present in all surface water. The "plankton" consist of:

(1) *Plants*—which include bacteria, fungi, algae and diatoms which feed upon and remove organic and some mineral matter.

(2) *Animals*—ranging in size from the microscopic protozoa, rotifera, up to the fishes. These feed upon both the plant and animal life present and build up food substances for human beings, completing the cycle of mineral, carbonaceous and nitrogenous matter in nature.

Given sufficient time, the natural forces of purification would accomplish their design but, with the artificialities and demands of civilization such as the concentration of population and the need of water supplies for other purposes than drinking or transportation, man has found it necessary to assist nature to supply him with a water suited to his needs. For our present purposes we are not so much concerned with the potability of a given surface or ground water, as with its chemical and physical characteristics, which affect its use industrially and more especially with regard to Rayon making and processing.

From a standpoint of potability a water should be free from turbidity, color, odor, pathogenic bacteria and excessive mineral matter. For Rayon making, the water must be free from color, turbidity, any organic matter subject to putrescence, or any excessive bacterial content, both pathogenic and saprophytic, and the hardness should be as near zero

as possible. Furthermore, compounds of iron and manganese are objectionable and should be removed, as they have a peculiarity of reacting with many of the chemicals and dyes encountered in the Rayon plant.

INDUSTRIAL IMPORTANCE OF MINERAL CONSTITUENTS FOUND IN NATURAL WATERS

The following remarks on the importance of the chemical constituents found in surface waters and their industrial implications are all excerpts from Water Supply Paper 496 of the U. S. Geological Survey, by W. D. Collins, entitled "The Industrial Utility of Public Water Supplies in the United States."

Silica.—Silica is dissolved from practically all rocks. Its state in natural water is not definitely known, but in reports of analyses it is assumed to be in the colloidal state, taking no part in the equilibrium between the acids and the bases.

Coagulation with aluminum sulphate makes possible the removal of fine silt by sedimentation and filtration, so that the effluents of filter plants contain less silica than untreated waters filtered through paper, and in considering the analyses of river waters used for a city supply that is filtered after the use of a coagulant it must be borne in mind that the quantity of silica is reduced by the filtration. The silica in most filtered waters is not so high as 10 parts per million, and in some it is less than 5.

As an insoluble constituent the silica in water contributes to the formation of boiler scale, and it sometimes helps to cement the other materials into a hard scale. Its presence or absence is said to have an effect on some of the exchange-silicate water-softening materials. On the whole, however, silica is of comparatively little importance in the waters of public supplies.

Iron (iron and aluminum oxides).—Iron is dissolved from practically all rocks and is frequently dissolved from iron pipes in sufficient quantity to be objectionable.

Iron is reported in all the analyses made by the United States Geological Survey and in most of the others. The figures given as iron in some analyses represent the quantity of iron and aluminum oxides. They do not show the minimum limit of the iron, but they do show its maximum limit, for the iron can not be more than 0.7 times the oxides.

Few surface waters contain in solution as much as 1 part per million of iron. In most of them the quantity is nearer 0.1 part. Many ground waters contain several parts per million of iron, which must be removed in order to make the waters satisfactory for domestic and industrial use. Water that contains much iron is objectionable on account of its appearance after exposure to the air and on account of the unsightly stains it makes on white porcelain or enameled ware or fixtures and on clothing or other fabrics washed in it. Smaller quantities of iron are said to cause trouble in the use of certain dyes. Excessive iron may interfere with the efficient operation of exchange-silicate water softeners.

Iron is almost completely removed by filtration as practiced at water-purification plants, but the treatment sometimes leaves the water in such condition that it can and does dissolve iron from pipes, particularly hot-water pipes. Some natural waters also have this property.

Aluminum is found only in negligible quantities in most natural waters. Under certain conditions of operation aluminum may pass through filters but in quantities too small to affect seriously the industrial use of the water.

Calcium and magnesium.—Though calcium and magnesium have somewhat different properties their effects upon the industrial uses of water are so much alike that they can not well

be treated separately. They cause hardness in water and together with the acid radicles in equilibrium with them make up from 60 to 90 per cent of the mineral matter of hard waters. Calcium and magnesium are also the predominating basic radicles in most soft waters.

The general industrial value of waters used for public supplies is more affected by calcium and magnesium than by any other constituents.

Sodium and potassium.—The sodium and potassium in the water of most public supplies have little effect on the industrial use of the water. Natural waters that contain only 3 or 4 parts per million of the two together are likely to contain about equal quantities of sodium and potassium. As the total quantity of these constituents increases, the proportion of potassium becomes less: waters carrying from 30 to 50 parts per million of the two may contain from 4 to 10 times as much sodium as potassium; waters carrying more sodium may contain smaller proportions of potassium.

Bicarbonate.—The usual methods of analysis lead to the conclusion that the carbon dioxide in most natural waters is present as bicarbonate (HCO_3) and free carbon dioxide (CO_2). A few natural waters contain little carbon dioxide and, therefore, show carbonate radicle (CO_3), which may be found also in water raised by an air lift that tends to sweep the carbon dioxide out of it. Many waters that have been treated with lime contain carbonate or even hydroxide. Some analyses show the composition of the residue on evaporation and, therefore, give carbonate instead of bicarbonate. In some partial analyses alkalinity is reported in terms of calcium carbonate (CaCO_3).

For uniformity and simplicity all results of determinations of alkalinity, whether expressed in terms of bicarbonate (HCO_3), carbonate (CO_3), or as equivalent calcium carbonate

(CaCO_3), are given in this report as bicarbonate (HCO_3). The small quantities of carbonate found in some samples may be due to the action of the sample on the bottles.

Bicarbonate is the chief acid radicle in nearly all the waters used for public supplies.

Sulphate.—Sulphate is not a very important constituent of the water of most public supplies. The quantity present affects the softening of the water and is affected by treatment with coagulants. An analysis of a river water before filtration will, therefore, show a smaller quantity of sulphate than that in the filtered water. A part of the sulphate in the water of some sources of supply is contributed to it by human activities. Many supplies in Pennsylvania receive sulphuric acid from the drainage of mines, even enough to make the waters acid, and some waters that are used for public supplies are contaminated by sulphuric acid or sulphates discharged from industrial establishments.

Chloride.—The water of only a few public supplies contains enough chloride to have any effect on its use for most industrial processes. The addition of chlorine or hypochlorite has no practical effect on the quantity of chloride radicle in a water. The chloride contributed by most rocks to a natural water rarely amounts to as much as 10 parts per million. Larger quantities are usually the result of contamination with water from deep wells or from deposits of common salt. Some industrial plants discharge chlorides, and a considerable quantity is added to many rivers by sewage from large cities.

Nitrate.—The effect of nitrate on the industrial use of water obtained from public supplies is so nearly negligible that results of determinations of nitrate could be omitted from the tables without great loss. A few waters contain enough nitrate to affect the calculated quantity of sodium or to increase the apparent error in an analysis in which sodium is determined and nitrate is not reported.

HARDNESS

Hardness in water is produced by calcium and magnesium. Other elements, such as iron, aluminum, strontium, or barium, would cause hardness, but these are not found in the water of public supplies in quantities large enough to have any appreciable effect.

Hardness may be recognized by the increased quantity of soap required to produce lather and by the deposits of insoluble salts formed when a hard water is heated or evaporated. Hardness may be determined by the use of a standard solution of soap, and although this method is not wholly reliable for some kinds of water, it should give accurate results with waters like most of those for which analyses are given.

Hardness can in general be determined more reliably by calculation than by the use of a soap solution. The hardness as equivalent calcium carbonate (CaCO_3) is 2.5 times the calcium plus 4.1 times the magnesium.

Hardness is by far the most important property of a water with reference to its general industrial utility.

Table 76, on next page, provides a form which may properly be used for compiling the information and analysis of water in its relation to industrial use:

Man has adopted the water purification process of nature and has developed devices and methods which accomplish desired results under definite control. These processes of purification are coagulation, precipitation, sedimentation, filtration and aeration. If a water supply contains color in excess of 10 and a turbidity due to colloidal suspension, or if it contains iron or manganese compounds, it must be treated with a coagulant or precipitant, which is usually a solution of alum. The alum combines with some of the dissolved impurities, such as the carbonates or bicarbonates, and

TABLE 75.—REPORT OF MINERAL ANALYSIS *

Water Resources No.....	Laboratory Number.....
Stream:	
Point Sampled:	
.....	County:
Stage of Stream:	Rate of Flow:
Drainage area above point of collection, or intake:	
Capacity of..... plant, millions of gallons per 24 hours.....	
Remarks:	
Collection by:	Date:
Analysis by:	Date:

	Parts per Million
Silica (SiO ₂).....	
Alumina (Al ₂ O ₃).....	
Iron (Fe).....	
Calcium (Ca).....	
Magnesium (Mg).....	
Sodium (Na).....	
Potassium (K).....	
Carbonate radicle (CO ₃).....	
Bicarbonate radicle (HCO ₃).....	
Sulphate radicle (SO ₄).....	
Chloride radicle (Cl).....	
Nitrate radicle (NO ₃).....	
.....	
Total dissolved solids at.....	
Total hardness as CaCO ₃ (calc.).....	
Color.....	
Turbidity.....	
Suspended matter.....	
Alkalinity.....	
pH.....	
.....	

Remarks:

* From the preliminary report on the chemical quality of the surface waters of North Carolina with relations to industrial use.

by hydrolysis forms a flocculent, gelatinous precipitate of aluminum hydroxide. This by agglutination as formed entraps suspended matter and bacteria and carries these down. The water may then be baffled through a settling basin, which accelerates the dropping of the precipitate.

Filtration is resorted to to complete the removal of suspended and precipitated matter. To increase the efficiency of filtration some of the gelatinous aluminum hydroxide is carried over to form a colloidal top coating for the filter. The rate at which matter can be filtered depends upon its condition. Highly turbid or colored waters require slower rates of filtration than less contaminated ones. A filtering rate of 2 to 3 gallons per square foot per minute is about the average for the usual conditions met with.

While it is entirely possible to design a water treating system and have it built by engineers to specifications suited to the water to be treated, it is just as well and perhaps better, in this case to take the water treating problems of the industrial plant to the builders of such special equipment. The Zeolite systems of water treatment have proved quite satisfactory and equipment based on this principle is offered by a number of manufacturers.

The following data on the Treatment of Textile Water Supplies are obtained from an article written by Mr. H. L. Tiger of the Permutit Company.*

Impurities and their Removal.—The following sources of fresh water are available for man's use:

(a) Surface waters, including flowing supplies such as creeks and rivers, and quiescent supplies, such as lakes and ponds.

(b) Ground waters, including springs, shallow and deep wells, and mine waters.

* Printed through Courtesy of the Permutit Company.

(c) Rain water, which, however, is difficult to collect in a clean condition on a large scale.

As water passes through the air it absorbs certain gases; as it flows over the surface of the earth or percolates through its crust, solid impurities are collected in suspended and dissolved form. The difficulties resulting from the presence of these impurities, particularly with respect to the use of the water in the textile mill, are outlined in Table 76:

TABLE 76.—IMPURITIES AND TROUBLES WITH TEXTILE-MILL WATER SUPPLIES

IMPURITIES	TROUBLES
<i>Suspended Matter</i>	Usually causes:
Inorganic (mineral) Sand and clay	1. Soiled yarns and cloth 2. Scratching of copper print rolls 3. Boiler deposits
Organic Living organisms (algae, etc.) Animal matter Vegetable matter Sewage Industrial refuse Oil	
<i>Dissolved Matter</i>	
Gaseous	
Oxygen	Principal cause of corrosion and pitting
Nitrogen	No effect
Carbon dioxide	May accelerate corrosion
Hydrogen sulphide	Offensive odor
Solid	1. Insoluble, sticky compounds with soaps, alkalis, and many dye-stuffs 2. Scale in boilers
Calcium and magnesium salts, i.e., hardness	No effect
Sodium and potassium salts....	Rust stains
Iron compounds (inorganic)...	Brown stains
Manganese compounds	Color lakes with dyestuffs
Aluminum compounds	
Organic compounds of iron and other substances	Stains and unsatisfactory bleach

The principles employed in removing the impurities enumerated above are outlined in Table 77. From this table it is apparent that

1. Coagulation and filtration reduce suspended matter, color, and organic matter to a minimum.
2. Aeration removes dissolved carbon dioxide or hydrogen sulphide and oxidizes and precipitates the inorganic iron compounds so that they can be removed by subsequent filtration.
3. Boiling with agitation in a vented container removes all the dissolved gases, including the oxygen.
4. Addition of alkali neutralizes the free mineral acid, or free carbon dioxide.
5. Softening with soluble chemicals removes part of the calcium and magnesium salts, leaving 2 to 5 grains of hardness per gallon, according to whether the process is carried out hot or cold.
6. Proper softening with zeolites completely removes calcium and magnesium salts, or hardness.

TABLE 77.—PRINCIPLES EMPLOYED IN REMOVING IMPURITIES

IMPURITIES	METHOD OF REMOVAL
<i>Suspended Matter</i>	Filtration alone, or coagulation and settling preceding filtration for complete removal
<i>Dissolved Matter</i>	
Gaseous	
Oxygen	Boiling in vented container
Carbon dioxide	Boiling or neutralizing with alkali
Hydrogen sulphide	Aeration
Solid	
Hardness	{ 1. Precipitation with lime-soda and filtration—partial removal. 2. Percolation through zeolite — complete removal
Iron (inorganic compounds) ..	Aeration and filtration
Manganese	Percolation through manganese zeolite
Alumina	Coagulation and filtration
Organic matter	{ Alum coagulation, settling, and filtration

It is thus possible in any given case to choose those methods which are required for the efficient removal of the objectionable impurities. We shall now proceed to consider the apparatus required for applying these principles to large scale water purification.

Chemical Control of Coagulation.—It should be mentioned here that although the improvements in the mechanical design and construction of feeds are partly responsible for the recent improved results, we should not overlook the influence of a better knowledge and control of the chemical processes themselves. For example, much work has been done during the recent past on the feeding of alum as coagulant in water treatment. It has been found that there are narrow limits of methyl orange alkalinity and free CO_2 within which the alum coagulates most effectively. These limits vary somewhat for various waters. Instead of determining methyl orange alkalinity and CO_2 one determination may be made, viz., that of the hydrogen ion concentration of the water. (This is usually expressed by the term $p\text{H}$ value.) It is thus possible to express the boundary limits of this optimum coagulating region for any given water by two figures (the lower and upper $p\text{H}$ values).

The value of keeping within this optimum region by careful control of the dosage is threefold:

1. The coagulation is more rapid.
2. The floc is larger.
3. The alum is completely coagulated and removed by the filter, so that no alum is present in the effluent.

Chemical Feeds.—Once the correct dosage has been determined, it remains for the chemical feed to add that definite amount of chemical to each gallon of water entering the treating plant. A chemical feed should be simple, foolproof, and rugged. It should have as few moving parts as possible, and if there are any orifices, they should be protected against clogging and be easily accessible for cleaning when necessary.

Chemical feeding devices may be divided into two general groups: dry feeds and solution feeds. The dry feeds are only practical where very large volumes of water are being treated,

such as in municipal water-purification plants. Solution feeds may be subdivided into

1. Manually controlled feeds which are set by hand to discharge at a given rate on the assumption that the flow of the water is sufficiently constant so that the dosage is within the required limits; and
2. Proportioning feeds, which automatically feed chemicals in proportion to the rate of the incoming water.

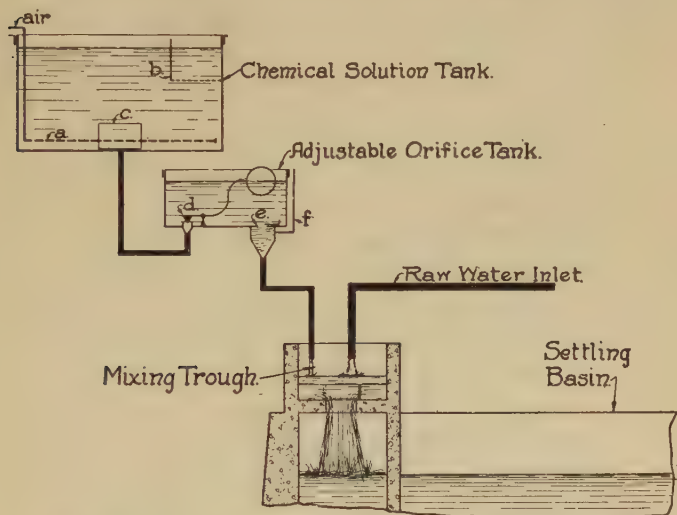


FIG. 42. Manually Controlled Orifice Feed, Gravity Type. (Courtesy Permutit Company, New York.)

Two manual feeds are illustrated: the gravity type and the pressure type. The gravity type manually controlled orifice feed (Fig. 42) consists of a solution tank in which sufficient chemical is dissolved for treating the water consumed in a definite period, usually one day.

The material of the solution tank should be suited to the particular chemical. Alum, being an acid salt, requires a wood tank. For alkalis, steel tanks are satisfactory. The dissolving tank should be provided also with a perforated dis-

solving basket or tray *b* into which the chemicals can be placed and through which there is free circulation so that the chemical dissolves readily. The tank should be provided also with a simple form of agitator *a* so that the contents may be agitated for a brief period to avoid stratification. A simple filter *c* is located at the outlet so as to strain out of solution such particles of solids as would enter the inlet float *d* on the orifice box, or settle on the adjustable orifice *e* with vent *f* and cause rapid clogging. A satisfactory type of filter for this purpose is a cylindrical wire-mesh frame containing gravel of 1/16-inch size. Care should be taken that the piping carrying the chemical solutions is adapted to the particular chemical. For alum, brass, lead, or rubber is found to be satisfactory, and for alkali, steel pipe is suitable.

The orifice tank is usually lined with porcelain to make it resistant to the action of any chemicals and the orifice should be of hard rubber and equipped with a graduated dial so that the opening can be set at any point corresponding to a definite discharge. The chemical is conducted through a pipe line to a mixing trough where it meets the stream of incoming raw water and is thoroughly mixed with that water prior to entering the settling basin. The chemical may also be conducted into a low-pressure line, such as the suction line of a pump, in cases where there is no settling tank or where the settling tank is located at some distance from the chemical feeds, and perhaps at an elevation above the chemical feeds.

The pressure type manually controlled orifice feed (Fig. 43), is similar to the gravity type except that the discharge is received in a vessel where it is diluted with a stream of water and the mixture is pumped into a pressure line or vessel. These feeds have the distinct advantage of simplicity and low cost, and where the chemicals make a clear solution and the rate of flow of raw water is fairly constant and continuous throughout the day, they are very satisfactory. Three pro-

portionating feeds are illustrated. The gravity type automatic stop-and-start orifice feed, Fig. 44, is the same as the simple orifice feed shown in Fig. 42, except that it is equipped with automatic control to stop and start the flow of chemicals in synchronism with the flow of the raw water.

A head box is used in order to prevent fluctuations in the rate of water entering the plant. This is accomplished by an inlet float valve controlled by float *p* which maintains a definite head over an outlet orifice in this head box. Float *g* in the

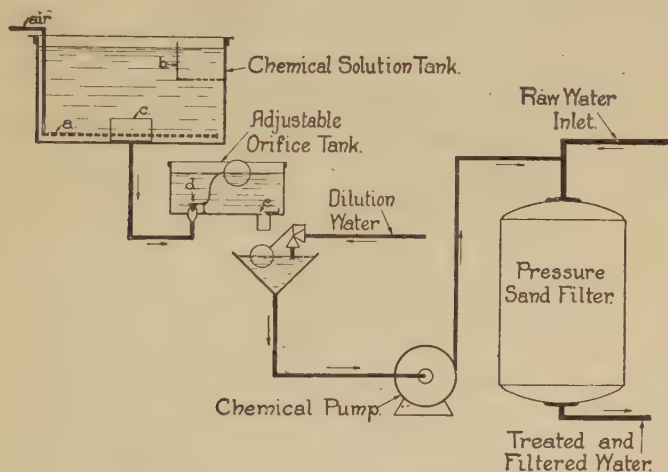


FIG. 43. Manually Controlled Orifice Feed, Pressure Type. (Courtesy Permutit Company, New York.)

main settling basin is connected to the same inlet float valve by a flexible connection so that it can close the inlet valve when the settling basin is full independently of the action of float *p*. In order to avoid variable rates due to throttled positions of the float valve when it is being closed or opened by float *g*, use is made of a device called a "float pot." An auxiliary float *i* operates valve *k* and closes the opening in the bottom of the float pot when the water level in the basin rises. The float pot then remains empty until the settling

basin fills and the water overflows into the pot. Therefore, the float pot is either entirely full or empty, and consequently float *g* either closes the inlet float valve completely or leaves it entirely free to be acted upon by float *p*. The small chemical float *h* which controls the chemical float valve is located in the same float pot as main float *g*, so that the flow of water and chemicals stop and start together. This feed is used only with clear chemical solutions and it must be located near the

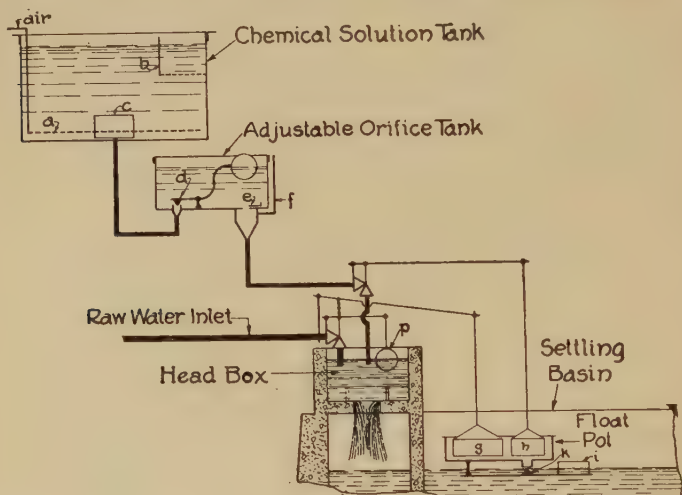


FIG. 44. Automatic Stop-and-Start Orifice Feed, Gravity Type. (Courtesy Permutit Company, New York.)

main inlet float valve so that the necessary lever connections can be readily made to operate the chemical float valve.

In the proportionating tipping-meter feed (Fig. 45) the main stream of water enters a head box and passes through an orifice *e* into the settling tank. A proportionate part of this stream passes through a smaller orifice *d* to the tipping meter *g*. This tipping meter consists of a two-compartment container *l*. The discharge from the dividing box *f* fills one compartment at a time, causing the meter to tip or oscillate.

This oscillating motion is transformed by levers, ratchet, and pawls to a revolving motion, and through a worm reduction gear this revolving motion is imparted to drum *h*. As this drum revolves it unwinds a chain supporting lift pipe *i* located in the chemical tank and free to swing at its lower joint *t*. Thus, the rocking of the container and the revolving of the drum cause the lift pipe to drop and a surface slice of chemical solution flows in through the open mouth *j* of the lift pipe

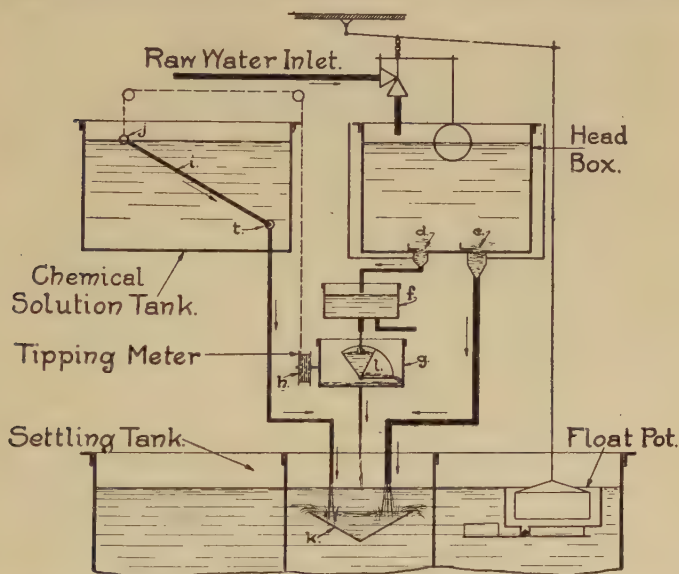


FIG. 45. Tipping-meter Feed, Gravity Type. (Courtesy Permutit Company, New York.)

into the settling tank, where it mixes with the raw water at the mixing baffle *k*.

Since the head on both the large and small orifices in the raw-water head box is the same, the ratio of the discharges from these orifices is the same at all rates of flow. Consequently the speed of the tipping meter and the rate of dropping of the lift pipe and the feeding of the chemicals are in

proportion to the rate of incoming water. This feed has the distinct advantage that there are no orifices in the lines which carry chemicals, and therefore the chemical solutions need not be clear. It has the added advantage that since the connection between the head box and the tipping meter is a small pipe, the feed can be located at ground level, placing only the head box on top of the high or distant settling tank. In such cases the chemicals are discharged from the solution tank into a

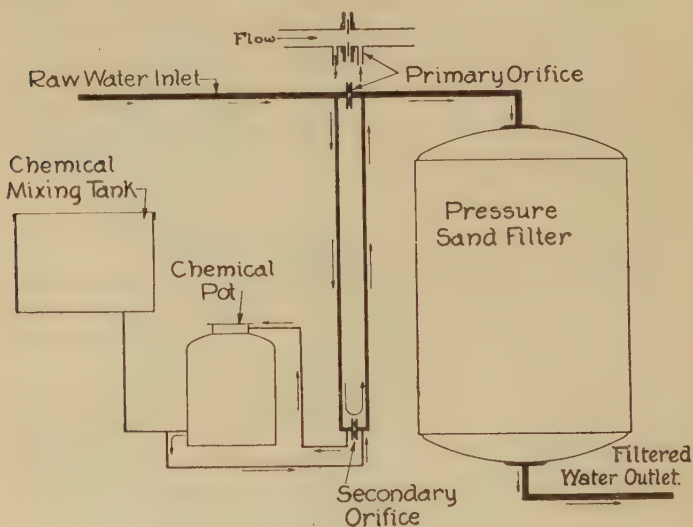


FIG. 46. Proportionating Feed, Closed Pressure Type. (Courtesy Permutit Company, New York.)

receiver and pumped to the mixing baffle in the settling tank where they meet the stream of raw water.

The proportionating closed pressure feed (Fig. 46) operates on the principle that an orifice in the main line causes an auxiliary proportionate stream to flow through the secondary line and secondary orifice. This secondary stream in turn causes a proportionate stream to flow through the chemical pot, from which it displaces an equivalent volume of solution

into the main line. These pressure feeds may be applied where it is undesirable to break the pressure line, in order to operate one of the open gravity feeds. The various feeds described above each have a certain field of application and it is therefore apparent that in each case it is necessary to make a careful study of the conditions in order to choose a type of feed best suited to the particular purpose.

Settling Tanks.—The purpose of the settling tank is—

(a) To allow time for the chemical reactions of treatment to take place prior to filtration.

(b) To prevent rapid clogging of the filters by collecting much of the suspended matter before the water enters the filters.

To accomplish this it is necessary to have sufficient volume and to utilize that full volume so that the time required for the water to travel from the inlet to the outlet of the basin, when the plant is operating at maximum rate, is long enough for the chemical reactions to be completed after water and chemicals have been thoroughly mixed.

At the same time it is necessary that the velocities of travel be low enough so that the suspensions can settle to the bottom in the form of a sludge, whence they are discharged at intervals. Experience indicates that for satisfactory sedimentation, which relieves the filters of a great part of their burden, the settling basin should provide a detention period from inlet to outlet of about four hours or longer, depending upon the character of the suspensions. In certain cases where the turbidities are comparatively low and coagulation is carried out principally for color removal, the volume of the settling tank may be decreased somewhat. In such cases however, it is necessary to make the filter area large enough so as to have a low rate of filtration and to avoid frequent clogging, bearing in mind that the settling tank has really become a reaction

tank and consequently the filters will collect most of the suspensions which would otherwise be collected in the larger settling tank.

Settling tanks are usually constructed as concrete basins on or below the ground, or as cylindrical steel or wood tanks on or above the ground. The shape of the settling tank and the baffling should be such that the water is uniformly distributed in the channels of flow and that the entire volume of

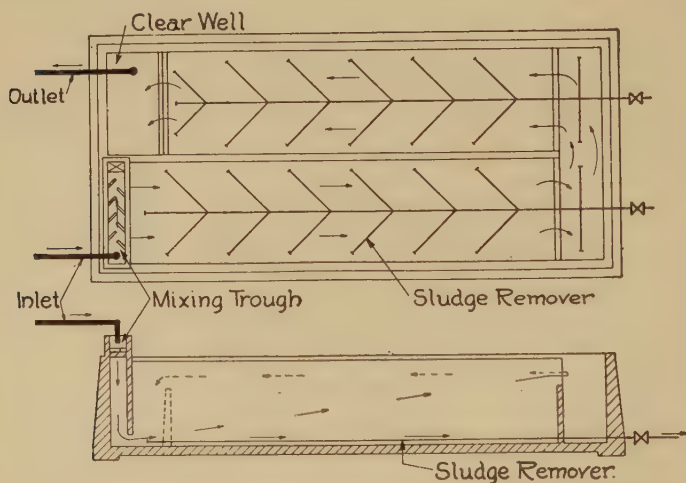


FIG. 47. Concrete Settling Basin. (Courtesy Permutit Company, New York.)

the tank is utilized. With this in mind the water depth in a rectangular concrete basin with horizontal flow should be limited, since excessive depth prevents utilization of the available volume. Figure 47 illustrates a concrete settling basin of this type. In vertical cylindrical tanks an approximate ratio of diameter to height of 2 to 3 lends itself readily to good baffling and to economy in the cost of the tanks. In such tanks a cylindrical baffle at the center, called a "downtake," is usually made about one-third the diameter of the tank, for

good results. Figure 48 illustrates such a cylindrical settling tank.

Filters.—The purpose of a filter is to remove the solids suspended in the water. If substances are present in a dissolved condition in the raw water, it is necessary to first convert them into insoluble form by chemical means so that the particles can be mechanically strained from the solution. This is the case with the removal of color by alum coagulation. The

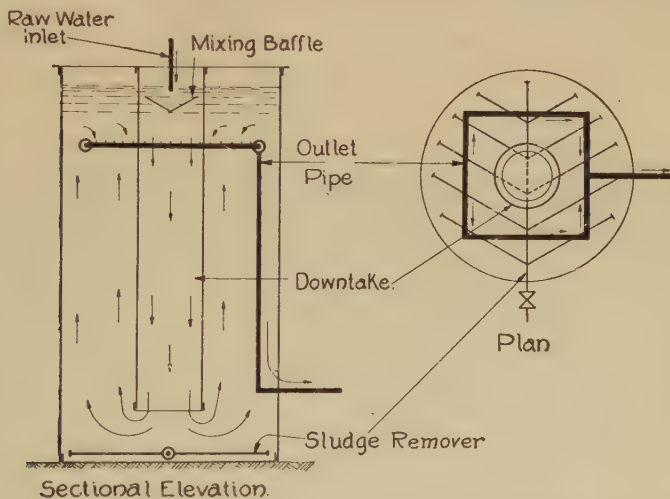


FIG. 48. Cylindrical Settling Tank. (Courtesy Permutit Company, New York.)

materials used in filtration are cloth, paper, porous plates, charcoal, crushed quartz and graded sand. The only material which is adapted to large-scale operation from an economic and operating point of view is sand, and we are therefore confining ourselves here to a consideration of sand filters.

1. Carefully washed, dried and screened sand and gravel layers of sufficient uniformity and of the correct size. Usually the effective size of the fine sand on top should be 0.4 to 0.5 mm.

2. Strainer systems which are designed correctly for uniform distribution, the orifices of which are of non-rusting material such as brass.

3. Wash outlet collector pipes.

4. Clean wash water at high enough rate, usually 10 to 15 gallons per square foot per minute.

5. Sufficient area to accomplish satisfactory filtration and to avoid excessive losses of pressure. Rates of 2 to 3 gallons per square foot per minute should not be exceeded.

There are two general types of rapid sand filters: open gravity and closed pressure. Figure 49 shows an open wood gravity filter and Fig. 50 a horizontal pressure filter. It has been claimed that better results are produced with gravity

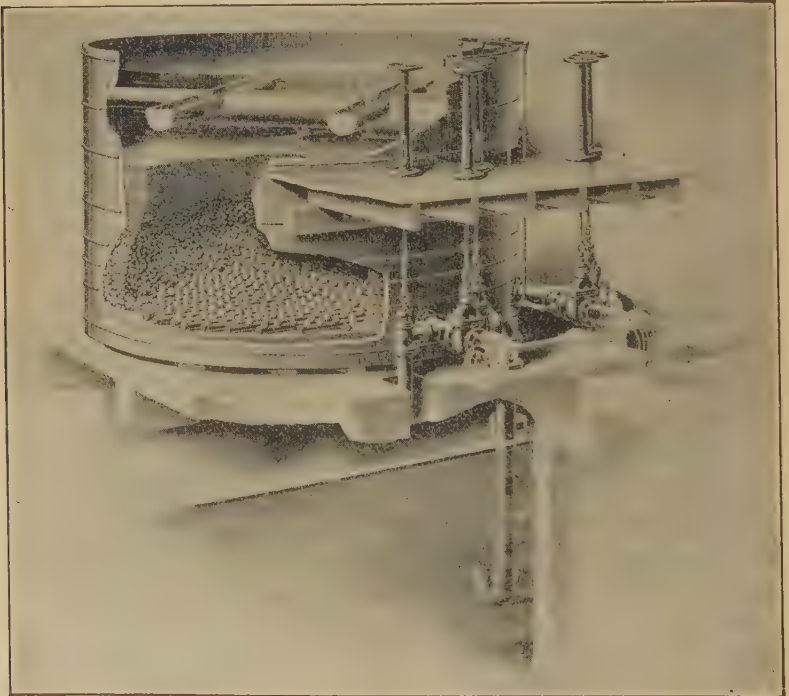


FIG. 49. Wood Gravity Filter. (Courtesy Permutit Company, New York.)

filters than with pressure filters, but in reaching these conclusions the error has often been made of comparing properly designed and operated municipal plants of the gravity type with improperly designed and operated industrial plants of the pressure type. There is no particular reason why the mere application of pressure should affect the quality of the effluent of a filter, provided the pre-treatment and rates of filtration are the same in both cases. The great advantages of pressure filter plants for industrial purification are the much lower initial cost and the elimination of repumping, with the accompanying loss of power that is often required by the gravity installation.

Iron-removal filters differ from the ordinary filter in that the action takes place throughout the sand bed rather than

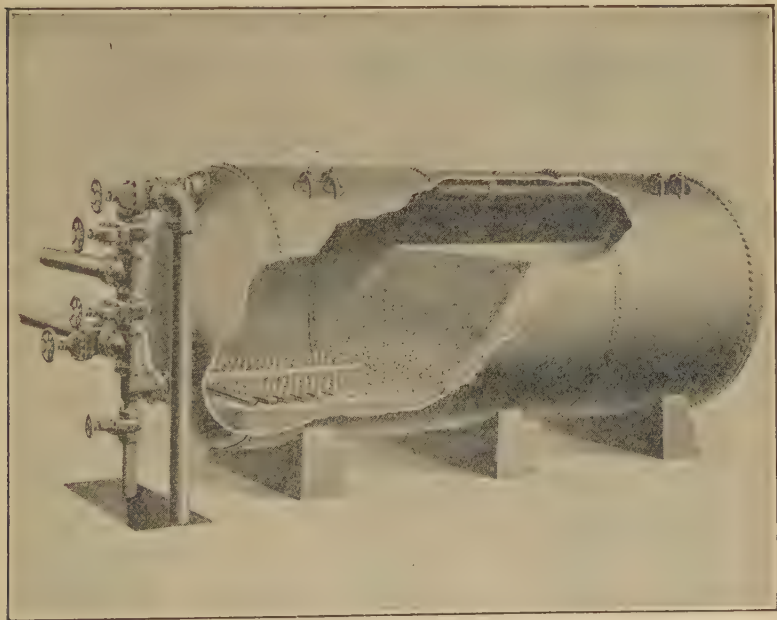


FIG. 50. Horizontal Steel Pressure Filter. (Courtesy Permutit Company, New York.)

only on top. The size of the filter is determined by providing a certain total time of contact between the water and the sand, depending on the amount of iron present. The iron is usually precipitated by aeration or chemical treatment first, and then the filter removes it. Air-wash strainer systems are required to assist the backwash water in order to dislodge the adherent iron precipitates from the sand.

Water Softeners.—The two general methods of removing calcium and magnesium salts mentioned in Table 77 are the precipitation process, where soluble chemicals are added and the resultant precipitates filtered off, and the zeolite process, where the water percolates through a bed of insoluble mineral which has the property of exchanging its sodium base for the calcium and magnesium of the hardness-forming constituents in the water. The chemicals most commonly used in the precipitation process are hydrate of lime and soda ash. The raw water is analyzed regularly and the dosage applied in sufficient amounts to react with the hardness and form the insoluble compounds of the hardness [calcium carbonate (CaCO_3) and magnesium hydrate ($\text{Mg}(\text{OH}_2)$)], which are partly removed in the settling tank, the remainder being taken out by sand filtration. In order to obtain a fair reduction in the hardness, it is necessary to add these soluble chemicals in excess, and thus the final treated water usually contains some of these chemicals in solution which are highly undesirable in textile process water.

The zeolite softener consists essentially of a bed of the zeolitic mineral, which is an insoluble sodium silicate, through which the water to be softened percolates. Since the reacting substance, that is, the zeolite, is insoluble, it may be present in great excess without any possibility of overtreatment, and thus the calcium and magnesium salts can be completely removed by the passage of the water through the bed. The water leaves the zeolite bed with sodium salts in amounts corre-

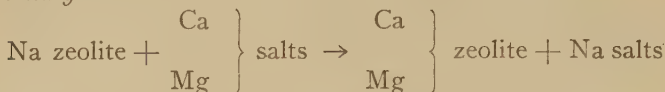
sponding to the calcium and magnesium salts removed: the process is a chemical exchange. Sodium salts do not form insoluble compounds with soaps (in fact, soaps are themselves sodium salts of fatty acids); neither do they form insoluble compounds with alkalis or dyestuffs, nor do they precipitate at concentrations which are reached in boilers. The effluent of such softeners is therefore ideal for textile process work and boiler feed. Many of the largest boiler plants are equipped with zeolite softeners for treating boiler feedwater and they furnish ample proof of the utility of such equipment in this field.

In general, there are two classes of zeolite; porous and non-porous. Porous zeolites are manufactured either by a fusion process in a furnace, or by a chemical precipitation process, or by baking and treating certain clays. The non-porous zeolite is manufactured by refining and treating the mineral glauconite, of which the best-known deposits exist in certain parts of New Jersey. The porous zeolites may be considered to have a sponge-like structure so that more surface is exposed to the action of the water per unit weight. The non-porous zeolite, on the other hand, is a round, greenish black, solid particle, with only the outer surface exposed for action. The initial exchange value is about one-half that of the porous, but this zeolite is very resistant to turbidity and aggressive water, so that its exchange value is unaffected even after long periods of use. Since the reactions take place on the surface, the zeolite can function at a high exchange velocity, both as to softening and regeneration. If it is overrun a few regenerations bring it back to its original condition.

From these facts it may be concluded that the porous zeolite requires smaller containers for removing the same amount of hardness. The initial cost for a given softening capacity, however, is about the same for both. The non-porous zeolite, being rugged and rapid in its action, is adapted

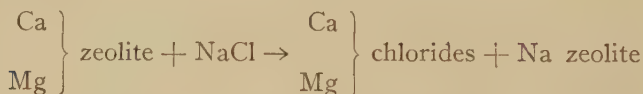
to most waters and conditions, even if some turbidity is present. The reactions which take place in the functioning of the zeolite are as follows:

Softening



When the bed is exhausted, the action may be reversed by treating with common salt (sodium chloride). This operation is called regeneration.

Regeneration



When the bed is exhausted and ready for regeneration, it is first backwashed in order to remove any dirt which has accumulated, and in order to stir up the zeolite so that the brine can regenerate all the particles. The zeolite is then regenerated, the brine is rinsed out, and the zeolite is again ready for the softening operation.

The capacity of a zeolite softener between regenerations is the product of the gallons of water treated and the hardness per gallon of that water. For example, 10,000 gallons $\times$ 10 grains per gallon = 100,000 grains. The capacity is the total weight (100,000 grains) of hardness expressed as CaCO_3 and not the gallons softened. Units should be selected large enough so that the regenerations do not take place too frequently. With mills running 8, 10 or 12 hours, one or at most two regenerations per working day should be used.

Zeolite softeners may be either of the closed pressure or the open gravity type. The latter are rarely used, however, because

- (a) This arrangement requires breaking the pressure

line with consequent loss of pressure and necessity of re-pumping.

(b) More head room and greater space are required for the larger area necessary to obtain the flow because only the gravity head is available. This is especially true on softer waters where the rate of flow per unit area is comparatively high.

Either vertical or horizontal shells are used as containers for the zeolite. Figure 51 illustrates a softener of the vertical

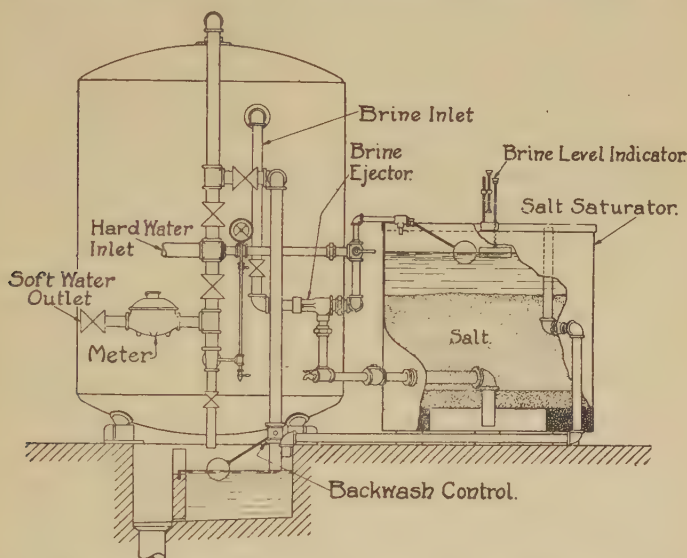


FIG. 51. Vertical Zeolite Softener. (Courtesy Permutit Company, New York.)

type. This softener has an inlet pipe to deliver and distribute the unsoftened water, and a strainer system imbedded in concrete and designed to carry away the softened water during normal operation when it flows downwardly and to uniformly distribute the incoming wash water as it enters the bed upwardly. It is necessary to exercise special care in the design of the strainer system of the zeolite softener so as to obtain

such uniform distribution of wash water. If some parts of the bed are not thoroughly washed, channels may form which permit the water to short-circuit a portion of the zeolite in the softener and consequently reduce the total softening capacity.

It is also necessary that the supporting materials of the zeolite bed be of the proper size and quality. Specially graded and washed gravels are usually used for this purpose. The gravel should be so small that it prevents the penetration of the zeolite into the gravel-supporting layer during normal operation, and at the same time be large enough so that there is no tendency for the gravel layer to mix with the zeolite layers during backwashing.

The rate of backwashing must be high enough to properly wash the zeolite, that is, to remove any dirt which has accumulated on the surface of the bed. At the same time it is necessary that the rate be low enough so that none of the zeolite is carried out of the softener and lost. In order to properly control this backwash rate without depending upon the operator, a simple automatic backwash-control device is applied. This (Fig. 51) consists essentially of a butterfly valve in the backwash outlet line which is controlled by a float riding on the surface of the water in a weir compartment in the sump. When the softener is first set in operation, this float is set for a maximum level above the weir and this corresponds to the maximum backwash rate. Thereafter it is only necessary for the operator to open the inlet and outlet valves wide during the backwash operation.

A meter on the softened-water line indicates the volume of water softened and when the rated capacity of the softener has been delivered, the softener is backwashed and regenerated. This regeneration may be done by passing the brine downwardly or upwardly through the bed. Figure 51 illustrates the arrangement with a simple salt saturator, in which

the salt is supported on a gravel layer, and as the water passes downward, it becomes saturated with salt. Thus the discharge of a given depth of liquid corresponds to a certain weight of salt and a float with indicator tells the operator at a glance when he has discharged the required amount of brine for a regeneration. The brine is discharged into the softener by means of a water ejector and when the necessary depth has passed into the softener, it is ready for rinsing. This consists of passing water downwardly through the bed to waste until all the brine has been rinsed out of the softener, which is indicated by a simple soap test showing the effluent is free from hardness.

Another type of salt-dissolving equipment which is used particularly in plants where large amounts of salt are consumed, is a concrete hopper saturator which may be depressed below the floor level for ease in handling salt. With this type low-grade run-of-the-mine salt can be used, whereas the salt saturator requires a clean salt. With this hopper saturator the insoluble materials in the salt settle to the bottom, whence they can be readily discharged as a sludge at intervals.

A properly designed zeolite softener provides:

1. Water of zero hardness.
2. Absence of any excess chemicals, because the softening medium is insoluble.
3. Simplicity of operation; no chemicals to control; results obtained with operation by man of ordinary intelligence, such as the average mill hand.
4. No moving mechanical parts—low cost of maintenance.
5. Direct connection into pressure line—no repumping.
6. Low cost of treatment— $\frac{1}{2}$ pound salt per 1000 grains hardness removed.
7. Clear waste liquids instead of objectionable sludges.
8. Constant absence of hardness in effluent in spite of variations in hardness of the raw-water supply.

In such large textile-water supplies as the Delaware River, for example, there are great and sudden fluctuations in the hardness at frequent intervals. Such variations seriously interfere with the standardization of the process work and consequently hinder production. The extreme variations in this case over the period of a year are from 30 to 160 parts per million, and when we consider the insoluble compounds which hardness forms with soaps, alkalis, and dyestuffs, it is not surprising that unexpected mysteries frequently arise in textile mills operating on unsoftened water.

Choice of Equipment.—The first step in solving a water-purification problem is to investigate the various sources of supply which may be available. If there is some question about a water shortage from a given source at any season (this source being otherwise desirable), the plant should be so designed that it can treat the water of poorer quality which it may be necessary to use during such seasons, bearing in mind that the primary consideration is to deliver an ample supply of pure water to the mill at all times and in spite of all raw-water conditions. The next step is to decide on the treatment required and the cost of delivering purified water from each source. An actual case will serve to illustrate the method. A certain mill is located near the bank of a river from which the city draws its raw-water supply. This raw water is turbid and colored, and requires alum coagulation and filtration for removal of these impurities. In addition, the water contains 3 grains of hardness per gallon, which it is necessary to remove from the entire mill supply of 300,000 gallons per day. At the same time there is available an ample supply of clear, colorless water from private deep wells, and this water contains 6 grains of hardness per gallon.

TABLE 78.—THE COMPARATIVE COSTS OF PURIFIED WATER PER THOUSAND GALLONS ARE:

	(1) City Water	(2) Raw River Water	(3) Water from Deep Wells
Cost of purchasing water.....	8.0		
Cost of pumping (delivery to mill at 30 lb. pressure).....	.....	3.0	3.0
Alum for coagulation at 1.6 cents per pound.....	.....	0.5	
Soda ash (for coagulation during periods of low natural alkalinity) at 2.0 cents per pound.....	.....	0.2	
Salt at 0.5 cent per pound.....	0.8	0.8	1.5
Operating labor.....	0.1	0.2	0.2
Interest and depreciation on initial cost at 15 per cent per annum....	1.0	2.0	1.7
Total cost, cents per 1000 gal. . .	9.9	6.7	6.4

The clear, hard well supply, in addition to being the cheapest, is also more desirable than the river supply because it requires only the simple zeolite softener without any pre-treatment.

Such an analysis involves also a decision as to the capacity of equipment to be installed. For this we must consider the volume of water consumed in each branch of the process work and the quality required. There are usually some branches of the work where the presence of a few grains of hardness is of no consequence and it may therefore be economical to use only clear, unsoftened water for such processes. In deciding this point it is necessary to balance the cost of the plant for softening the entire supply against the cost of the plant for softening a portion of the supply and installing the extra piping required for carrying both softened and unsoftened

water. We should also consider that it is usually undesirable to have various qualities of water in the mill, particularly when there is danger of operatives using unsoftened water in the wrong process. When all factors have been weighed, it is usually found advisable to soften the entire supply rather than a portion, except in those cases where large volumes of unsoftened water may be conveniently used. Once the source and capacity have been determined, it is a simple matter to choose the equipment required in accordance with the fundamental principles outlined previously.

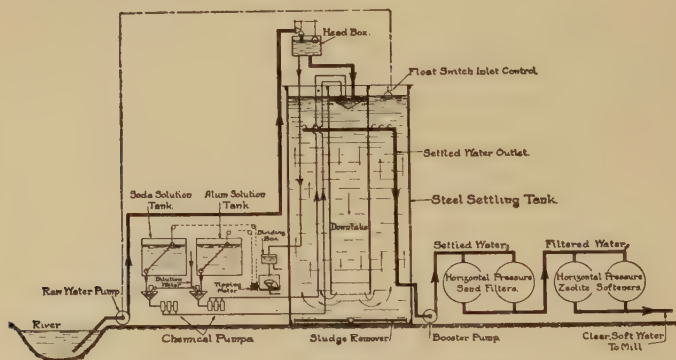


FIG. 52. Typical Modern Filtration and Softening Plant. (Courtesy Permutit Company, New York.)

A Typical Modern Installation.—Figure 52 illustrates a typical modern water-purification plant. This type of plant has been installed in many textile mills during the past few years. In this case, the raw river water is treated with coagulant as it is discharged into the main settling tank by raw-water pumps. The dosage of alum and soda ash is controlled by a tipping-meter feed, which, for convenience, is located at ground level, the chemical being discharged into receiving tanks whence they are pumped to the inlet of the downtake where they meet the stream of entering raw water. A pump discharges the settled water through the pressure

filters and zeolite softeners, and delivers it directly to the mill under the desired pressure.

The flow of raw water is controlled by an automatic device so that when the settling tank fills, the raw water stops flowing through the head box to the settling tank and to the tipping meter. Consequently the chemical flow stops also. When the chemical tanks are empty, an electric alarm notifies the operator to place a new charge. In addition to this the only attention required is to backwash the filters and backwash and regenerate the softeners about once a day and de-sludge the settling tank once in several days.

Sources of Contamination.—Even after the water supply has been properly purified it is necessary to take precautions to make certain that the water used in the process work is of the same quality as that delivered by the treating plant. In one case a large open concrete tank was used as storage basin for the purified water. This water lying stagnant in the open sunlight became a breeding place for algae and animal growths, which entered the plant and stained the cloth. In another case small black particles in bleached cotton goods were traced to an uncovered storage tank on a tower not far distant from the boiler plant. An occasional breeze carried cinder particles from the stacks of the process vats into the water.

Occasionally also the process vat itself may be the cause of contamination. Some experiences which might be mentioned are: leaching iron from concrete bleach tanks used for silk hosiery; organic matter from digestion of wood kiers by caustic boil-off liquors in boiling off cotton; iron flakes from the rolls of cotton skein mercerizing machines; iron-laden condensate from steam lines leading to the steamer in a woolen mill. Cases have even been observed where leaky by-pass valves or unknown lines have contaminated an entire supply of purified water.

RELATION OF WATER TO PROCESS

We have seen that the principal objection to hardness in textile process work is the fact that it forms insoluble compounds with soaps, alkalis, and many dyestuffs. These suspensions represent waste, and when they deposit on the fibres they prevent uniform results. Figure 53 illustrates the deposits of insoluble soap curds on woolen fibres processed in unsoftened water, whereas Fig. 54 shows the same fibres proc-

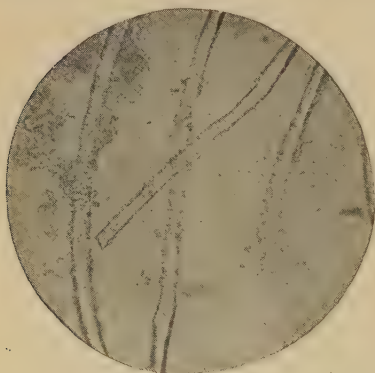


FIG. 53. Showing Deposits of Insoluble Soap Curds on Woolen Fibres Processed in Unsoftened Water. (Courtesy Permutit Company, New York.)

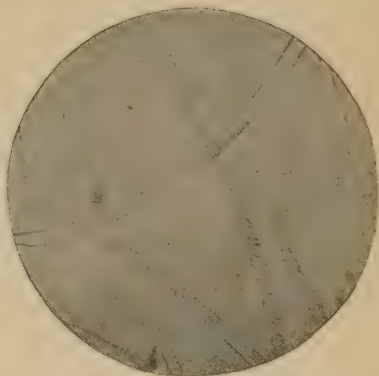


FIG. 54. When Processed in Water Free from Hardness. (Courtesy Permutit Company, New York.)

essed in water free from hardness. It is clear that such deposits will prevent the uniform penetration of dyestuffs or other chemicals in the processes which follow. In the kier-boiling step in the manufacture of cotton goods, any insoluble suspensions which are formed in the process liquors will collect on the surface of the yarn or cloth, which acts as an excellent filtering medium for these suspensions. It is clear that the process liquor should be absolutely free from such adherent suspensions, which in turn demands clear, colorless water of zero hardness.

Much has been done recently in the way of dyeing yarn wound on perforated spools. This process depends upon circulating the dye liquor through the layers of yarn from the outside to the center of the spool, the direction of circulation being reversed at intervals for obtaining uniform results. Here again water of high purity is demanded because insoluble suspensions will be filtered out by the outer and the inner layers and many cases have been observed where such defects in the finished product have been entirely eliminated by properly purifying the water supply.

In woolen manufacture the fibre with its fir-cone structure readily grasps and holds any insoluble curds which may be formed in the scouring baths, and such deposits have a distinct detrimental effect upon the spinning and drawing qualities of the wool fibre and on the subsequent mechanical processes of manufacture. In silk manufacturing subsequent processes of manufacture are endangered if insoluble curds are permitted to deposit upon the fibres during the soaking which is carried out for the softening of the silk gum (or sericin), or during the degumming which is carried out for the removal of this gum.

The striking progress of the Rayon industry during the past few years again illustrates the necessity for water of high quality in a rapidly growing branch of the textile industry. Experience has shown that the quality of the water used in making the Rayon fibre plays an important part in the same manner as the quality of wood pulp which goes into the manufacture of that fibre. This effect has been so striking that the largest builders of Rayon plants have decided that any water supply, irrespective of its natural composition, should be treated so as to insure the process with an unfailing supply of clear, colorless water of zero hardness.

4. *Considerations as to air conditioning or temperature and humidity regulation.*

Both ventilation and accurate temperature and humidity control are necessary and must be provided to meet the different requirements for the four distinct processes.

Ventilation is necessary to remove the various gases which are given off during the process, such as Hydrogen Sulphide (H_2S) given off in spinning viscose solution, as otherwise these gases would prove dangerous to the workers and surrounding community if not removed with some degree of rapidity through ventilation. All the four processes start with wood pulp, cotton linters or flax and in order to convert this cellulose vegetable product into a liquid mass of the proper viscosity and subsequently force it through a platinum spinneret hole of say three-thousandths of an inch in diameter and instantly coagulate into a filament by warm air or some chemical solution, it is necessary to introduce accurate temperature controls. Due to the hygroscopy of the Rayon yarn during the process and when it is a finished yarn, the control of humidity of the air is also essential.

In the final departments of all the processes the yarn goes through the same handling as natural silk. It is bleached, washed, dried, sorted and packed and made ready for shipment in skeins or shipped on bobbins, spools, beams or cones. In order that the moisture or water content of the Rayon yarn does not vary greatly from a fixed ratio in these finishing departments it is necessary that both humidifying and dehumidifying equipment be introduced in these parts of the plant.

The problems involved in this phase of engineering having to do with air regulation have been long receiving proper attention toward complete solution, for it was largely due to these gradual improvements that a practically uniform Rayon yarn has been produced.

In the design of a Rayon plant the air-regulating system is a large and important part. With plants covering areas often reaching hundreds of thousand square feet and cubic content reaching millions of feet, the air conditioning presented, until recently, two problems to conjure with, arising from the fact that the control of all the air was carried out from one single station, with air ducts emanating from this station in all directions of the plant to points where ventilation of a certain temperature or humidity was needed. While the method of the central station has proven efficacious, it is not as simple, elastic or less costly than the recently developed unit system of air regulation.

It is the author's belief that this unit system, already widely applied in other industries, will come in general use in the future Rayon plants. Mr. H. P. Gant, past President of the American Society of Heating and Ventilating Engineers, has discussed this subject in a simple and interesting manner in an article * part of which is given here with reproductions of a few types and sizes of air-conditioning units:

The successful Rayon producer is successful only so long as he is able to control the chemical processes in his plant. This is possible to a great extent only when the atmospheric conditions in the plant are controlled.

In many Rayon processes, temperature and humidity control are vital to the aging and proper completion of chemical reactions.

Frequently exhaust systems must be installed to remove objectionable fumes or odors, and the air introduced into the room to replace the air which has thus been exhausted must be controlled and properly conditioned. In fact, it is practically impossible to control the temperature and humidity in a Rayon plant without the use of properly designed air conditioning equipment.

Textile Sections.—In the spinning room of a Rayon plant, it is important to control the relative humidity and temperature in

* Rayon Journal, 1927.

many different kinds of processes, and some require a very high relative humidity to prevent crystallization. In other processes un-conditioned air entering the room through open windows is a detriment.

Where injurious or objectionable odors are given off, they must be removed at the point of generation, and it is important at all times to accurately and automatically control the volume of air removed by exhaust systems. The replacement air introduced into the room must be controlled both in temperature and humidity.

In twisting, winding and reeling, the proper conditions are most important. In the final drying, inspecting and sorting the proper humidity has an important financial bearing, as a manufacturer who permits his product to dry below the trade allowances suffers a financial loss. In many cases, it has been demonstrated that the proper atmospheric condition in the finishing department has shown a financial return sufficient to offset the investment for conditioning equipment within a few months.

Throwing.—To the throwster properly controlled atmospheric conditions are essential, as the chief difficulty experienced in the manufacture of Rayon in the past has been the presence of shiners. Shiners occur principally in winding rooms, and are due to unusually high humidities. Proper air conditioning in the throwing department will entirely eliminate shiners as well as many other difficulties known to throwsters.

Conditioning is also useful in weaving and spinning as it serves the same purpose to Rayon that air conditioning does to natural silks and other textiles.

Progress of Art.—The evolution of air conditioning as applied to the Rayon industry has grown as rapidly as the production of Rayon itself. This has been brought about by the close co-operation of the architect and textile engineer with the air-conditioning engineer. On no other process have the textile engineer, architect chemist and air-conditioning engineer worked so closely to perfect the wonderful results that have been obtained.

The central system of air conditioning has successfully demonstrated its ability to automatically and definitely maintain pre-determined temperature and humidity conditions throughout various Rayon plants, and without such a system the Rayon

manufacturers would have found it difficult, if not impossible, to produce high-grade Rayon on an economical cost basis.

The central system of air-conditioning consists of tempering and re-heating coils, a large humidifier, sometimes known as an air washer, a large motor driven fan and a very elaborate and carefully designed system of distributing ducts usually made of galvanized steel suspended from the ceiling or roof trusses for the purpose of conveying the conditioned air to various parts of the plant.

Obviously, such a system of necessity was designed to fit exactly a given installation, and after being designed, the component parts of the system were fabricated and the installation then made. Frequently the time required to design, fabricate and install a central system proved excessive, and another drawback to such a system was that the cost was frequently so high that the investment could not be justified.

A central system properly designed and operated will give excellent results, but it possesses no flexibility as it is essentially a "tailor-made" job designed to fit a given plant capacity and not capable of being modified or extended if later required by building extensions or changes in plant processes.

In building a new plant, an owner naturally tries to look to the future and so construct his plant that it will meet all of his requirements for years to come, but frequently he finds that he must very quickly modify the plant, adding a floor or an extension, or changing the location of a department or adding additional machines.

When any of these changes are made where a central air conditioning system is installed, the system becomes obsolete as it cannot be extended or the capacity increased to meet the increased demand placed upon it by these changes.

The central system of air conditioning may be compared to a central fan blast system of heating which was, until a few years ago, a very popular method of heating industrial plants where air conditioning was not necessary. The central fan blast system of heating was designed to replace the former method of factory heating by the use of direct radiation.

Within the past five years, however, the unit system of factory heating has almost entirely replaced the central fan blast

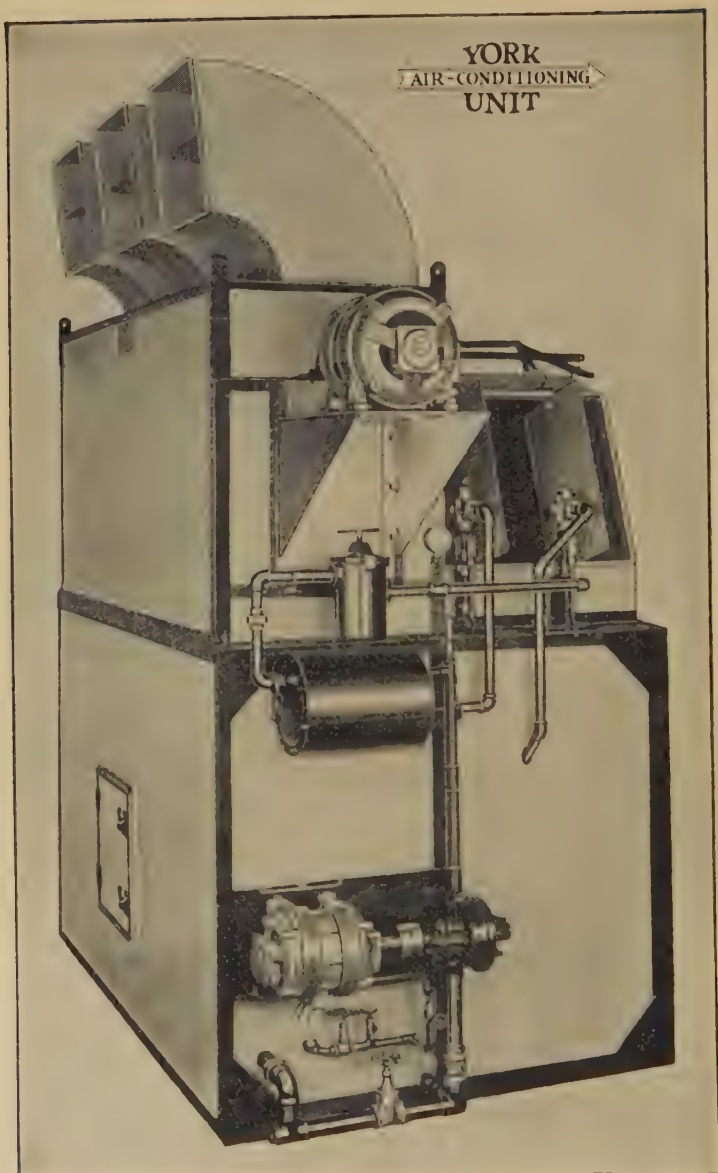


FIG. 55. Air-conditioning Unit—Capacity 5,000 cu. ft. of Air Per Minute.

system, and now in the art of heating and ventilating has appeared the unit system of air-conditioning bearing the same relationship to the central air-conditioning system that unit heaters bear to the central fan blast heating system.

While recognizing the advantages of the central air-conditioning system and at the same time acknowledging that there are limitations to such a system both as to cost and lack of flexibility, air-conditioning units have been designed along very simple and compact lines, and they offer every advantage of the central air-conditioning system, but possess none of the disadvantages.

These units are available in various capacities ranging from 750 to 10,000 cubic feet of air per minute, and as they have been standardized so that they can be manufactured in quantity, it is no longer necessary for a plant owner to wait months before an adequate conditioning system can be installed in his plant. The cost of installing the unit system is much less, and the actual installation is greatly simplified, for it is only necessary to place the units on the floor and make simple steam, water and electric connections.

Where air-conditioning units are employed, no distributing duct systems whatever are required as these units operate on the well-known principle of discharging the conditioned air horizontally from each unit at high velocity above the heads of the workers without creating drafts, and these streams of high velocity air induce the flow of a large additional quantity of surrounding air, thus producing a uniform mixture of conditioned air throughout the building and automatically maintaining extremely uniform temperatures and humidities.

When air-conditioning units are to be installed in a plant, it is, of course, first necessary to determine the total capacity required, and then install the correct number of units of proper capacities to balance the total requirements.

It will be seen that as no distributing duct systems are employed, it is a very simple matter to add additional units to compensate for plant extensions or changes in manufacturing processes, or to re-locate units as desired. This gives an extremely flexible installation, and one very distinct advantage of the unit system of air-conditioning is that the units may easily be installed in existing plants without offering any interruption whatever to normal plant production.

Air-conditioning units may be installed where it is desired either to humidify or dehumidify (reduce the normal moisture content of the air), or to cool the air, thus maintaining a lower temperature within the building than the outside temperature. Units of this type have been standardized so that they are inter-

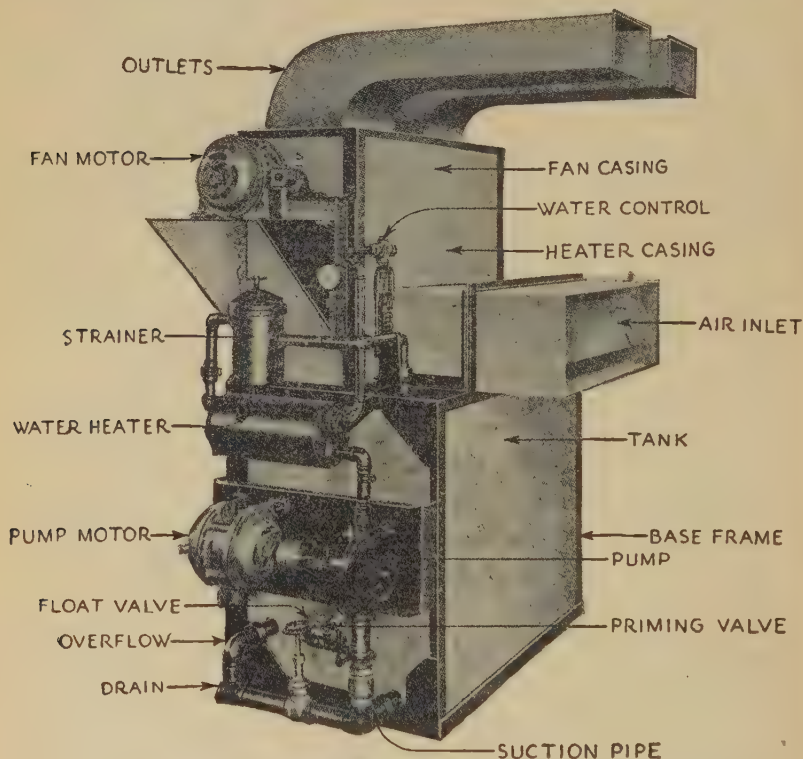


FIG. 56. Air-conditioning Unit—Capacity 2,500 cu. ft. of Air Per Minute.

changeable for either humidifying or de-humidifying by merely adding insulation to the cold surfaces, and introducing refrigerated water through the sprays when the units are used for de-humidifying.

These units contain the necessary heating elements so that they not only condition the air but heat the plant as well, and

for this reason no direct radiation is necessary for heating purposes when air-condition units are used.

In the past, when considering the installation of air-conditioning equipment, the mill owner was forced to completely condition his plant, or go without any air conditioning, for the central system necessarily had to be built for the maximum desired capacity. This meant that a large investment was necessary for the job could not be done piece-meal. By employing the unit system, however, one department at a time can be equipped with air-conditioning units until the plant is completely equipped.

Frequently it is necessary to maintain a definite atmospheric condition in one department continuously, while other departments may only require conditioning during the daytime. The unit system is invaluable in such cases for only those units need be constantly operated which are installed in departments requiring continuous conditioning.

The distribution of air from an air-conditioning unit is first checked by means of a smoke bomb. A dense volume of smoke is drawn into the unit and then discharged through the outlets into the room. The air distribution is thus visibly observed. Then the temperature and humidity are carefully checked at various points in the room by means of a sling psychrometer or other accurate instrument.

Where air-conditioning units are installed, it has been found that there has been practically no variation whatever in temperature and humidity at any given level above the floor.

An interesting experiment may be made to show the effect of varying humidity on a hygroscopic material, if a small piece of note paper about 2 inches square is placed on the open palm of the hand, the paper will gradually curl upward. If the paper is then reversed, it will curl in the opposite direction. This is due to the fact that the lower side of the paper quickly absorbs moisture from the hand, while the upper surface of the paper is dry. If the paper is placed in a room where the humidity is constant, there will be no curling.

Thermostats are provided throughout the plant which automatically maintain the temperature and moisture content uniformly at the points desired.

5. *Considerations as to power, steam and fuel.*

Power is not a large item with the Rayon industry. Approximately 650 kilowatts generator capacity would be required for a Rayon plant of one million pounds annual production. This is not a large unit of electrical power when compared with the textile industry other than Rayon. However, the power question is important, as the spinning department operates on a 24-hour load which requires that power whether purchased or manufactured, should be continuous. It is often found that it is cheaper to buy the current rather than produce the small amount required. Since considerable hot water is used in the process it is frequently found economical to install power plant equipment to generate both the steam for heating the water and the plant and the steam power for the generation of the electrical power.

The question of power for the Rayon plant is largely a matter of local conditions. Since the process is a continuous one every precaution should be taken to insure an ample power supply, which is not subject to complete cessation at any time. Some plants may be located in such a manner as to take advantage of natural water power. However, the present available water powers are no longer as accessible to the channels of trade, and it would not necessarily follow that choice of site should be made from such a consideration alone. However, with improvements in transmission the more remote and inaccessible water powers have a potential value in considering the power phase of plant location.

With the cheapening of transportation costs and the lowering of prices of solid fuels, especially bituminous coal, and with the growing steam plant efficiencies due to improved methods of combustion by means of automatic stokers and powdered fuel burning equipment, the deciding factor in most problems of plant location has become the question of labor supply.

For the Rayon plant materials and labor represent almost 80 per cent of the total cost of the finished yarn, and the cost of power and steam for processing rarely exceeds 6 per cent of the total. Therefore, a slight fluctuation of the power item one way or another would not affect ultimate costs very materially. The main consideration as far as power is concerned is constancy of supply. To insure this as well as an adequate supply of process and conditioning steam, the most advisable modern installation would consist of high pressure boilers equipped with super-heaters of at least 100 degrees of super-heat and economizers and fired with powdered coal. Steam turbines running on about 15-pound back pressure would be used for generating electric power and bled for process steam and that necessary for auxiliaries. Furthermore it would be advisable to have an adequate reserve equipment and also, where possible, to have a tie-in with central station power. It is also advisable to use individual motor drives in all divisions of the Rayon plant.

The following tables are presented for comparison of costs of various types of power. They represent average conditions of efficiency and are based on a coal cost of \$7 per ton in

TABLE 79: COST OF STEAM POWER USING TURBINES

Size of Plant, in Kw.	1000	2000	3000	4000	5000	6000
Boiler House, No. Stories.....	1	1	1	1	1	2
Type of Stokers.....	Hand	Hand	Hand	Hand	Hand	Hand
Coal Handling Method.....	"	"	"	"	"	"
Cost of Plant per Kw.....	\$178	\$152	\$130	\$120	\$110	\$133
Coal Used, Lbs. per Kw-hr....	3.1	2.7	2.6	2.5	2.4	2.2
<i>Power Cost, Burning Coal</i>						
Yearly Cost, per Kw.....	\$55.00	\$47.00	\$44.00	\$41.00	\$39.00	\$38.00
Cost per Kw-hr. in cents.....	2.56	2.18	2.04	1.90	1.81	1.79
<i>Power Cost, Burning Oil</i>						
Yearly Cost, per Kw.....	\$58.00	\$48.50	\$45.00	\$42.00	\$39.00	\$43.00
Cost per Kw-hr., in cents.....	2.66	2.24	2.10	1.94	1.81	1.95

bunker and oil at \$2 per barrel in storage tanks. Continuous operation at 150 per cent rating and 250 degrees superheat at a load factor of 90 per cent is also assumed.

Process and conditioning steam requirements run about 75 per cent of the total.

TABLE 80: REDUCTIONS IN COST OF POWER, EFFECTED BY THE USE OF EXHAUST OR BLEEDER STEAM

Low Pressure Steam in Per Cent of Total.	25	50	75	100
<i>Savings in Power Cost</i>				
Yearly Savings, per Kw.....	\$7.00-\$10.00	\$12.50-\$13.50	\$18.00-\$23.50	\$23.50-\$30.50
Savings per Kw-hr., in Cents.....	0.33-0.45	0.58-0.63	0.85-1.10	1.08-1.42

TABLE 81: APPROXIMATE COST OF UNIFORM HYDRO-ELECTRIC POWER
Delivered at Power Plant Switchboard

Size of Plant in Kw.....	1000	2000	3000	4000	5000
Assumed Plant Cost, per Kw.....	\$100.00	\$100.00	\$100.00	\$100.00	\$100.00
Power Cost, per Kw per year.....	14.00	13.25	12.50	11.75	11.00
Power Cost, per Kw-hr., in cents....	.65	.61	.57	.53	.50
Assumed Plant Cost, per Kw.....	\$200.00	\$200.00	\$200.00	\$200.00	\$200.00
Power Cost, per Kw. per year.....	25.00	24.35	23.45	22.60	21.75
Power Cost, per Kw-hr., in cents....	1.17	1.13	1.09	1.05	1.00
Assumed Plant Cost, per Kw.....	\$300.00	\$300.00	\$300.00	\$300.00	\$300.00
Power Cost, per Kw. per year.....	36.20	35.30	34.40	33.55	32.65
Power Cost, per Kw-hr., in cents....	1.70	1.65	1.60	1.55	1.50

Delivered at Consumers' End of Transmission Line

Size of Plant in Kw.....	1000	2000	3000	4000	5000
Assumed Plant Cost, per Kw.....	\$300.00	\$300.00	\$300.00	\$300.00	\$300.00
Power Cost, per Kw. per year.....	39.80	38.80	37.80	36.90	35.90
Power Cost, per Kw-hr., in cents....	1.87	1.82	1.76	1.71	1.65

TABLE 82: APPROXIMATE COST OF VARIABLE HYDRO-ELECTRIC POWER

*Power Costs per Kilowatt per Year for Hydro-Electric Plants Having
Steam Auxiliary Power Plants*

Size of Plant, in Kw.....	1000	2000	3000	4000	5000
Cost of Hydro-elec. Plant per Kw....	\$200.00	\$200.00	\$200.00	\$200.00	\$200.00
Yearly Cost, Hydro-elec. Plant per Kw.....	\$25.00	\$14.35	\$23.45	\$22.50	\$21.75
<i>Auxiliary Steam Plant</i>					
Yearly Fixed Charges, per Kw.....	12.50	12.50	12.50	12.50	12.50
Operating Cost each month per Kw..	3.25	2.75	2.50	2.40	2.30
<i>Total Yearly Power Cost per Kw.</i>					
Steam Plant running 1 month.....	40.75	39.60	38.45	37.50	36.55
Steam Plant running 5 months.....	53.75	50.60	48.45	47.00	45.75

6. Considerations as to Research Laboratories and development:

The plans for research and development should be elaborated to provide for every facility which will encourage the men assigned to this task to rapid progress, for no other industry presents the opportunities for results, which can emanate from research work, as does the Rayon industry.

A chemical Rayon laboratory need not be used for research and development alone, but also for the periodical routine batch tests, usually taken every hour.

A research division as proposed here should contain a complete small Rayon making unit carrying out the process from the raw pulp to the finished skein, in other words, a duplication of the main plant on a small scale to permit of experiments with new raw materials, chemicals and modified methods of Rayon making.

With research laboratories at hand, with the usual exertion given the various problems by the research engineers and with all other facilities at one's command as a result of prac-

tically unlimited capital, it is not difficult to guess what may be accomplished in the future. Even now there may be in process of development in these well-guarded laboratories, data which will revolutionize the science of Rayon production. While Rayon is yet quite unlike real silk, it may be brought very close to it in quality if not in feel and luster, and when this is accomplished its production will be continuously increased to meet an increasing demand.

It is possible, and quite probable, that these research laboratories may in time become responsible for the development of new equipment to replace the present type which comprise a great many pieces of apparatus and large floor space. Such development may prove so revolutionary that in time an entire Rayon plant may be incorporated within the space required by the spinning machine alone, that is, immediately after the yarn is drawn from the acid solution, a machine may successfully wash, dry and form the skein. Such an accomplishment would tend to reduce the cost of production considerably which with the advent of a better quality of Rayon, would increase its demand far beyond the estimate of anyone.

7. Considerations as to transportation and yard traffic regulation:

The site must be so selected and the plant built thereon in such a way as to be properly balanced with regard to railway facilities. At least one railroad system should pass by and spur into the yard. Where the location is a junction of two railroads the conditions are superior. The planning of railroad spurs with regard to incoming raw materials and the shipment of finished Rayon yarn are all part of the engineering program and must of necessity be considered in conjunction with selection of the site, with the preparation of the building plans and with due consideration for the expansion of the business.

8. *Labor and labor living conditions:*

As previously discussed at some length, the question of an adequate labor supply of the proper temperament and training is a very vital one. A personal nucleus properly selected and trained is necessary for the success of any Rayon plant. The proportion of labor cost in the total cost of Rayon bulks large and much attention is being given to ways and means whereby this can be cut down. The improvements in processes and machinery are bringing about considerable reductions in the total number of required operators. There is a tendency for wages to rise so that labor-saving improvements may be somewhat offset by increased rates of pay. This condition of rising wage rates also holds in Europe so that the labor advantage there may not continue to be so real as it once was.

Conditions of labor are different in the South of the United States as against the North. Longer hours are permitted by the laws of the States in the South which, coupled with plentiful labor at lower rates of wages, has had an influence in attracting many of the Rayon companies to the South, particularly the four States, West Virginia, North Carolina, Georgia and Tennessee.

Rayon plants should preferably be built near towns of at least 5,000 population so that all or part of the labor may be drawn from this population. In European sections whole villages have been built to provide for labor homes. Due to the fact that the number of people employed is large, in fact, much larger than in any other field of the textile industry, it would require considerable capital for the erection of a village. In some cases, where villages have not been built, large dormitories were erected to supplement the labor supply.

At all events the location of a Rayon plant near a small town has the advantage of a stabilized labor supply without interruption and without the competition which would arise were the plant located in the industrial area of a larger

town. When this condition cannot be found it is better to go to a secluded point where all the natural advantages exist, in which case a village must be provided, with due consideration to finding employment for all the men, as the greater percentage of labor is female, reaching almost 60 per cent of the total labor required.

When the plant is somewhat out of town, proper transportation facilities must be provided for the workers. The plant having to cover a large area must be quite a distance from the residential section of a city. This is the more necessary due to the gases which a Rayon plant develops. It can be readily seen that where such a large body of intelligent labor is needed subjected to careful training, it is most important to study every condition in the selection of a site which will be conducive to the happiness of all the employees of a Rayon plant.

The *Wall Street Journal* published the following comparisons based on American wages at one hundred. Table 83 shows the increase in foreign wages during a six-months' period of 1925 and also shows the prevailing rates as compared to our average wages as standard:

TABLE 83

City	Jan., 1925	June, 1925	City	Jan., 1925	June, 1925
Philadelphia.....	100	100	Paris, France.....	33	38
Ottawa, Canada.....	69	81	Berlin, Germany.....	29	34
Sydney, Australia.....	70	77	Lodz, Poland.....	27	33
London, England.....	45	55	Brussels, Belgium.....	28	32
Copenhagen, Denmark..	41	53	Prague, Czechoslovakia..	29	28
Amsterdam, Holland....	37	46	Warsaw, Poland.....	23	28
Oslo (Kristiania)			Rome, Italy.....	23	27
Norway.....	38	45	Milan, Italy.....	21	27
Stockholm, Sweden.....	36	40	Vienna, Austria.....	23	26

Some interesting data on working hours were published in the Journal of the Textile Institute based on information supplied by The International Labor Office at Geneva. These are summarized below and concern hours of work as laid down by law or else in effect by agreement between employers and employees. Hours of work as at present actually worked in the textile industry are, of course, far from normal, but

TABLE 84: HOURS OF LABOR

Country	HOURS OF LABOR			Authority	Remarks
	Per Day	Per Week	Per Year		
Austria.....	8	48	..	Act 17-xii, 1919	Lower Austria by agreement, 30-vi, 1922.
Belgium.....	8	48	..	Act 14-vi, 1921	Special arrangement for flax retting; see below.
Czecho-Slovakia.....	8	46	..	Act 19-xii, 1918	
Denmark.....	8	48	..	Agreement 17-v, 1919	Came into force 1-i, 1920.
France.....	8	48	..	Decree 12-xii, 1919	
Germany.....	..	46	..	Agreement 22-i, 1919	Denounced by employers 4-xi, 1920. Regional agreements now in force, all for 46 hour week.
Great Britain.....	..	48	..	Generally under Trade Boards Act, 1909-18.	Agreements vary with sections of the industry.
Italy.....	..	48	..	National and collective agreements.	Mainly effected from 1920-1922.
Netherlands.....	8	48	..	Act 20-v, 1922.	
Poland.....	8	46	..	Act 18-xii, 1919.	
Spain.....	8	48	..	Decree 15-i, 1920.	
Sweden.....	..	48	..	Collective agreement.	Valid up to 1-iv, 1924. No subsequent record.
Switzerland.....	8	48	..	Act 27-vi, 1919.	
United States.....	..	..	..	A report published in March, 1920 showed that in 239 undertakings an average of 53 hours per week were worked.	

are not dealt with here. The particulars can be classed naturally into three groups:

(1) Those dealing with the hours per day, week or year, and with variations in the actual hours worked as caused by rest periods, holidays, etc.

(2) Those referring to specific branches of the textile industry and

(3) Those having reference to individual countries.

So far as possible particulars under groups (1) and (2) are assembled under the country to which they refer, and a tabular form is adopted to facilitate easy reference.

Modifications of the general provisions set forth exist and they vary, as has been indicated, in different branches of the textile industry and in different countries. Particulars of special regulations are not available in every case, nor, in every case, can it be ascertained whether the regulations do or do not apply to the textile industries specifically. Among the more interesting topics dealt with are overtime, holiday and Sunday work, Saturday afternoon cessation, cleaning time, night duty, and regulations relating to special work. The following notes may be of interest:

Overtime is generally provided for in the regulations at hand. For periods of overtime worked consecutively with the normal hours of work, workers receive, generally speaking, from 20 per cent to 40 per cent increase in hourly wages. When extra time is worked during the hours from 10 P.M. to 6 A.M. the rate of pay generally increases by percentages from 50 to 100. Austria seems to be an outstanding country in this respect, since, according to the data available, workers on overtime are paid a uniform increase of 100 per cent, and this applies to Sundays and holidays. Certain specified holidays, however, are not paid for at all. In general, provision is made that overtime shall not be worked by workers under 18 years of age. In Belgium extra time is only worked upon special occasions and with the

consent of the trade union concerned. In certain countries—France, Italy and Spain—the maximum hours of overtime that may be worked in any one year are stated; these range from 120 hours to 500 hours per annum.

Saturday cessation: There appears to be a fairly general attempt to secure Saturday afternoon as a holiday, for even in cases where it is not part of the compulsory scheme it forms part of alternative schemes; such is the case, for example, in France and Belgium, but to secure the half-day in Belgium not more than nine hours may be worked on any one day. In other cases the hours of work are reduced on Saturdays in such a way as to allow of a fairly early cessation of work. In Poland, for example, six hours only are worked and in Sweden only $5\frac{1}{2}$ hours may be worked on Saturdays.

Cleaning times, rest periods, etc.: Only occasional mention is made of provisions for these matters and from those that do occur it is suggested that these periods are not, as a rule, included in the eight hours a day. In Czechoslovakia, however, mention is made of the condition that if overtime is worked on cleaning that consumes an hour or more than an hour, such work is paid for at overtime rates.

Night Work and Special Regulations: The materials available seem to recognize in a fairly uniform way that shifts may impose more stringent conditions upon work-people. Thus, in Austria, where a worker is doing one night shift and one day shift alternately, he receives an increase of 10 per cent in hourly wages, but when he works two night shifts to one day shift, he gets 15 per cent increase for his night work, while if working entirely on night work he receives an all-round increase of 20 per cent. Special regulations provide for extra hours to be worked in Belgium by those engaged on flax retting, whether in "wells" or rivers, but in these cases not more than nine hours per day may be worked.

9. *The Engineering of process details:*

The engineering of process details have reached the present state of development through a period of many years—

over sixty years. The history of this development has already been told in the previous chapters of this book and the actual technics which control the chemistry of these processes are covered in the chapters which describe the four processes for making Rayon, the viscose, the nitro-cellulose, the cupra-ammonium and the acetate silk.

The engineering of plant design covering that phase of the work which is more or less standardized and is not susceptible to as great a development as the process or equipment can be conveyed to the reader by pictures of various plants and by cost figures and principal factors which are given in the following. In connection with this we refer the reader to Chapter XVI, where views of a number of American and European Rayon plants are shown.

A Rayon plant of a capacity of 2,000,000 pounds per year (approximately 3 tons daily) requires the following:

Cost for buildings and equipment, \$2,500,000.

Floor space of buildings, 200,000 square feet.

Employees required, 1,000.

Power required in kilowatts, 1250.

Fuel required, coal per day, 50 tons.

Water required per day, 1,500,000 gallons.

In considering the location the investigation should consider not only the labor, power, fuel and water costs given above, but also the ratios of each of these to the total cost, a table for which is given below:

	<i>Per cent of total cost</i>
Raw materials.....	25
Direct labor.....	43
Engineering staff and administration.....	10
Water, fuel, light and power.....	6
Supplies and repairs.....	6
Insurance, taxes and depreciation.....	10
Total	100

An example of an operating Rayon plant of considerable size, producing 10,000,000 pounds of Rayon yarn per year and employing 4,000 operatives is the Old Hickory plant in Tennessee of the Du Pont Rayon Company. This plant is located in a beautiful section of the Cumberland River valley, about 12 miles from Nashville. Being quite out of the city it has its own village. Chapter XVI gives a pictorial view of two units of the Du Pont Rayon plants in Tennessee.

CHAPTER X

PRINCIPAL RAW MATERIALS

THE Rayon industry as a continual chemical process depends for its success on a continuous supply of raw material with constant chemical properties.

Cellulose.—The principal basic raw material of all existing commercially successful processes for making Rayon, is cellulose, the physical properties of which are of prime importance. Cellulose, which is the most prolific substance in nature, is a carbohydrate of complex molecular structure resulting from all plant growth. It is composed of carbon and the elements of water—hydrogen and oxygen. Cellulose belongs to the polysaccharid group of carbohydrates having the formula $(C_6H_{10}O_5)_x$, in the same class with starches and sugars, and though the chemist succeeded in the synthesis of many of the sugars he has failed to build up cellulose artificially and hence its structure is as yet unknown. In the case of the cellulose molecule it is considered to be four times in the base; so that the molecular formula of cellulose becomes $C_{24}H_{40}O_{20}$.

It is certain, however, that the structure of cellulose is a highly complex one; the most recent advances in X-ray spectrography, which provide the chemist with a new means of attack in elucidating complex organic structures, tend to show that he is dealing, not with a series of individual molecules, but with definite aggregates of molecules—molecular complexes, which determine certain physical characters peculiar to cellulose and which may vary in type according to its origin.

And it is certain that the arrangement of these molecular complexes, altered as they are during the conversion of cellulose into artificial silk, determines the fundamental properties of the commercial fibre. It was demonstrated during the War, in the course of experiments made on the production of nitro-cellulose for cordite manufacture, that a relation exists between the state of molecular aggregation of cellulose and nitro-cellulose (gun cotton) prepared herefrom, as evidenced by comparative measurements of the viscosities of solutions of the parent substance and derivatives in suitable solvents.

That such a relation exists between the raw material used in Rayon production and the finished product there can be no doubt. Starting with a basic cellulose of high molecular complexity, and, allowing for the degenerative influence of the various processes in the manufacture of any type of Rayon, one would expect to obtain a product of relatively high molecular complexity, and, further, as a relation undoubtedly exists between the size of the component molecular aggregates and ultimate strength of a cellulose fibre or filament, a relatively stronger product.

Cellulose is present in all vegetable products such as wood pulp, straw, cotton, paper, hemp, ramie, etc., but since the uniformity of the raw material is of utmost importance in Rayon making it has only proven practical to consider cellulose from two sources for this purpose namely, wood pulp and cotton. Furthermore, this choice is also influenced by a consideration of the cheapness and constancy of the supply.

Wood Cellulose—Wood Pulp.—By this term we understand the fibrous mass of plant cells which have been separated from incrusting materials (lignin) and resin. The chemical composition of wood is quite variable and depends upon variety, age, season, climate where grown, part of the tree whether sapwood, corewood of the trunk or branches, etc.

TABLE 85.—AVERAGE ANALYSIS OF COMMON KINDS OF WOOD

Kind	Per Cent Water	Per Cent Cellulose	Per Cent Lignin	Per Cent Resin
Birch.....	12.48	55.52	28.21	1.14
Beech.....	12.57	45.47	39.14	0.14
Boxwood.....	12.90	48.14	35.70	0.63
Ebony.....	9.40	29.99	48.08	2.54
Oak.....	13.12	39.47	34.30	0.91
Alder.....	10.70	54.62	31.33	0.87
Linden.....	10.10	53.09	29.32	3.92
Chestnut.....	12.03	52.64	28.82	1.10
Mahogany.....	12.39	49.07	27.61	1.02
Poplar.....	12.10	62.77	20.88	1.37
Willow.....	11.66	55.72	28.74	1.23
Pine.....	12.87	53.27	28.18	1.63
Fir.....	13.87	56.99	26.91	0.97
Spruce.....	12.05	55.01	29.02	1.01

It follows therefore that wood pulp will show a wide range of composition depending on the particular kind and location of the timber from which it was made.

Besides the constituents of wood mentioned above we also find present hemicellulose, pentosans, mineral ash, tannins and coloring matter which carry over to a greater or less degree to the prepared pulp fibre used in the Rayon industry. These are impurities, excessive amounts of which will disturb the Rayon process, and therefore they must be confined to certain limits.

Long fiber, wood-pulp cellulose free from resin is adaptable to the Rayon industry and the wood species exclusively used for the production of Rayon pulp are the spruces. As the supplies of highest grade spruce wood are exhausted, attention will turn to such timber as the aspen poplar and the paper birch, the stands of which could supply the needs of the Rayon industry for many years to come. The fibres of the

evergreens are as a rule longer than those of the deciduous trees.

The quality of chemical wood pulp to be used in the production of Rayon depends upon the following factors:

1. The quality and uniformity of the wood.
2. The type of process applied.
3. The control of the various steps in the process.
4. A careful examination of the pulp produced.

1. *The wood.*—As stated before, the wood species exclusively used for the manufacture of Rayon pulp are the spruces. The chemical composition of sound spruce wood will be approximately as follows:

Cellulose, 52 per cent.

Lignin, 29 per cent.

Fats and resins, 3.3 per cent.

Pentosan and hexosan (the so-called hemicelluloses),
14 per cent.

Proteins, 0.7 per cent.

The ratio between these various constituents may vary depending upon the conditions under which the tree has grown. In the manufacture of pulp, however, not only the chemical properties, but also the physical properties are of importance. With physical properties there are designated changes such as for instance, the density of the wood, that is, the rapidity with which the wood has grown, and it therefore follows that to produce successfully a pulp of this special character it is necessary that control be had over the supply of the main raw material—wood.

The wood giving the best results is a slow growth type of Northern Canadian spruce, yielding a very uniform raw material for the manufacture of wood cellulose (Fig. 57). The wood used is selected and cut from chosen areas, waterborne to the mill, and here the bark is removed before the logs are stacked uniformly in piles, allowing air to circulate between

the logs, resulting in equalization and removal of the excess moisture and furthermore imparting other desirable properties to the wood. This seasoning process takes months.



FIG. 57. Typical stand of Northern Canadian spruce. (Courtesy of Canadian International Paper Co., Kipawa Mills.)

The Kipawa Mill of the Canadian International Paper Co. with its 4000 square miles of Northern Canadian spruce meets the conditions for a high quality Rayon pulp, other pulp makers, in the United States and Europe, realizing the importance and great future demand for this product are also making great strides.

2. *The Process:* The processes by which pulp is prepared from logs of wood are three: Namely, the soda process, the bisulphate process and the bisulphite process. These are processes where active chemicals are brought into contact with wood reduced to chips about $\frac{1}{2} \times 1$ inch, at high temperature and pressure for the purpose of dissolving the incrustants (lignin). This chemical reaction naturally has some effect on the fibrous cells, themselves. Neither pulp produced by the soda process nor pulp produced by the bisulphate process is usable for Rayon making, for such pulp lacks solubility, uniformity and the necessary porosity or capillarity. Wood pulp prepared by the Ritter-Kellner modification of the bisulphite process is the only pulp so far adapted to Rayon making.

The process used in manufacturing wood pulp is practically all of a chemical nature and rather complicated.

The object of the process is to remove constituents such as lignin, fats, resins, hemicelluloses, in such a manner that the cellulose remains in the purest possible form not only free from woody substances but also intact and free from decomposed cellulose.

To this end the wood after being barked and selected (Figs. 57A and 58) (all foreign spruce and decayed wood must be sorted out) is, after careful inspection, being reduced to small chips $\frac{7}{8}$ inch long, $\frac{1}{2}$ inch wide, $\frac{1}{4}$ inch thick. This is obtained by pressing the log against a revolving disc on which are fixed radially 3 or 4 knives. These chips are next carefully screened so as to remove sawdust and over-size. The finished

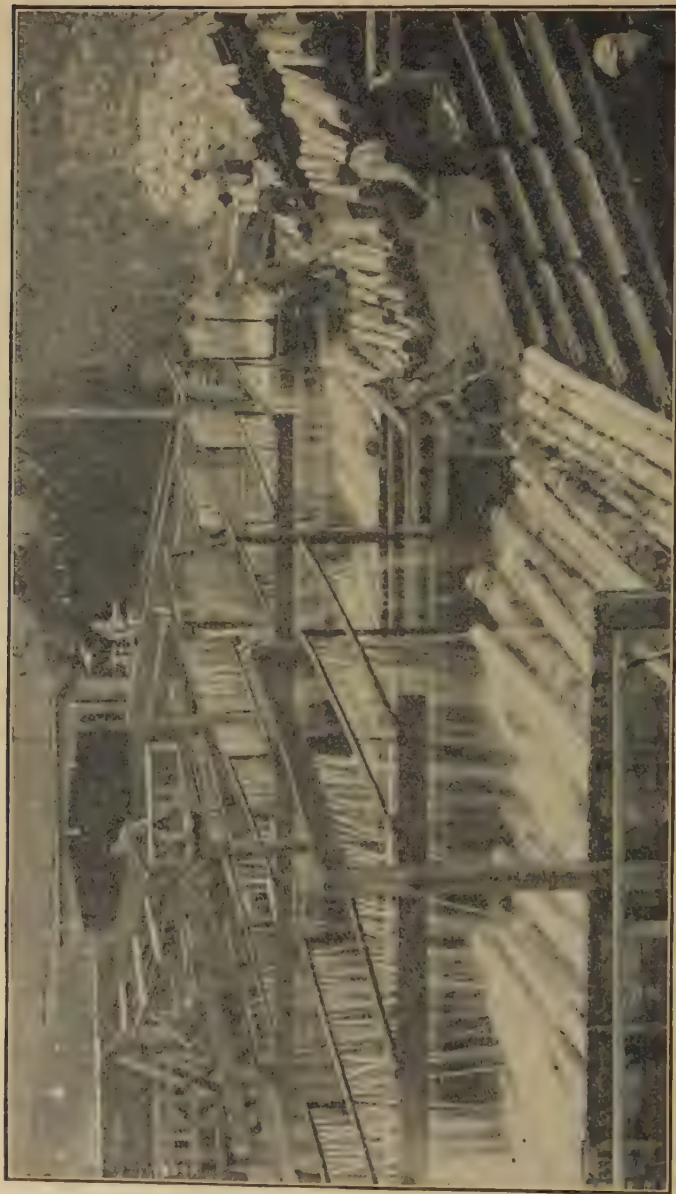


FIG. 57A. Barking plant. (Courtesy of Kipawa Mills.)



Fig. 38 Wood storage, after selection and seasoning. (Courtesy of Kipawa Mills.)

chips now reach the storage bins above the digesters ready for further processing (Fig. 59).

The dissolving out of the incrusting substances is carried out by hydrolysis with a solution of calcium bisulphite. Cellulose itself is practically resistant towards this agent while the other constituents of wood, such as lignin, hemicellulose are removed.

This calcium bisulphite solution is produced in the sulphite mill by carrying cooled sulphurous acid gases (obtained by the burning of sulphur in a current of air) into large towers filled with limestone over which is percolating cooled water.

The resulting "raw acid" is next enriched by the surplus gases from the digesters and now reaches the storage tanks ready for use.

The digesters, Fig. 59, holding as much as 36 cords of wood, are filled with chips and acid. The cover is now put on and steam introduced. After a period of about 14-15 hours the cook is finished and the content of the digester blown into large rectangular chests with perforated bottom where all traces of acid are washed away. The pulp consists of fibre bundles which must be broken up and foreign matter, such as uncooked wood, knots, etc., must be removed. To this end the pulp is diluted to approximately $\frac{1}{4}$ of 1 per cent consistency and floated over large screens (Fig. 60) where the fiber of the proper size is sucked through slots $\frac{7}{10000}$ - $\frac{8}{10000}$ of an inch width. As a last cleaning the pulp is allowed to run over large tables at a slow speed where all sand and metal particles settle out.

The cleaned stock suspension is now concentrated to about 30 per cent consistency and ready for the final step in the purification process, that of the bleaching.

The object of bleaching is to remove the last traces of lignin and small amount of coloring matter, giving the pulp a perfect white color.



FIG. 59. The Digesters holding 36 cords of wood. (Courtesy of Kipawa Mills.)

The thickened stock is mixed carefully with a previously determined hypochlorite solution and continuously carried to a large porcelain lined tower where it slowly sinks towards bottom. The tower is being kept full while a slow current of air passes through the pulp on its way downward.

In this apparatus the pulp is only partly bleached. It must next be washed and is at last given the final bleaching at a low density in large horizontal chests where it is kept constantly in movement. When finished the liquor is removed and all traces of chlorine washed out.

The final step in operation is now to convert the pulp suspension into pulp sheets of proper density, thickness, and for this purpose a machine very much like a paper machine is utilized. The pulp is flowing on to an endless wire where part of the water is removed while the sheet is formed. The sheet is next carried to a set of presses for further removal of water and the last traces of water are evaporated by carrying the continuous sheet over a set of drying cylinders (Fig. 60A). Finally the pulp is cut into sizes as requested by the customers and baled ready for shipment (Fig. 61).

3. *Control of the various steps in the process:* For this a large staff of chemists and skilled helpers is required. Every step in the process must be carefully supervised and observations made to see that it follows standards laid down. For instance the chips must be examined for their uniformity, the cooking acid for its regularities of composition, in the digesters the cooking operation must be followed by recording temperature and pressure gauges and continuous analysis of the cooking liquor, in the bleachery the composition of the bleach liquor and the bleaching process itself must be followed step by step. During the process of making the pulp into sheets the operation is continuously under supervision so that the sheet finally comes from the machine with a proper thickness, proper density, the proper sheet formation and a



FIG. 60—Screening Room.

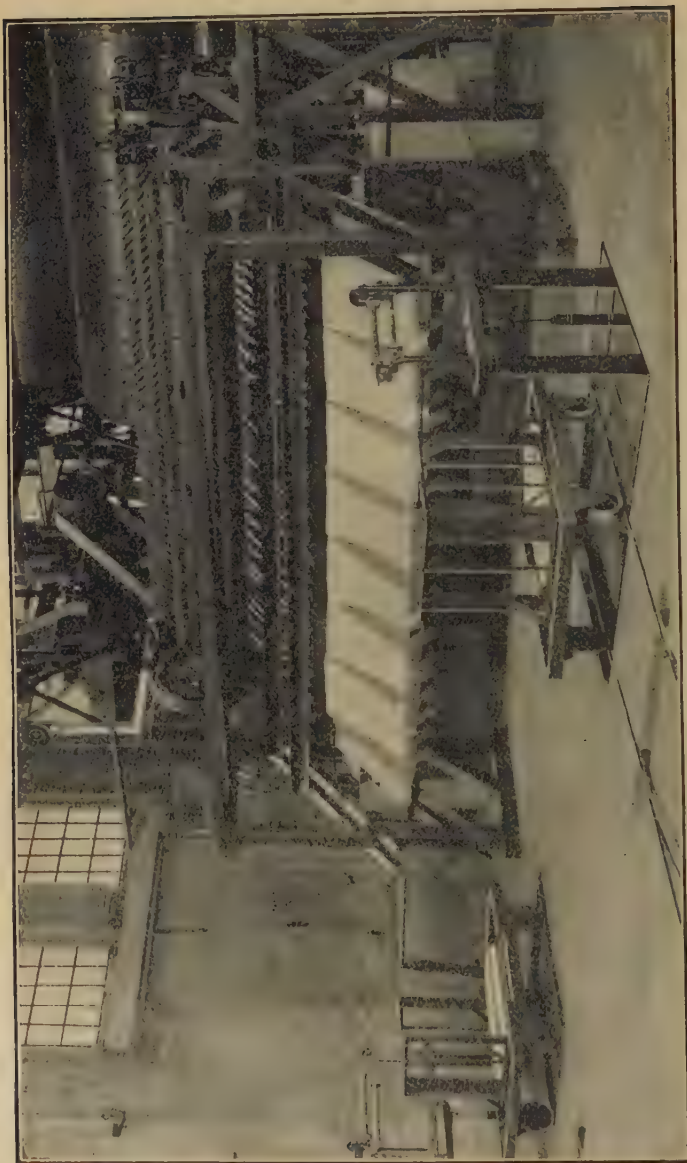


FIG. 60A. Drying machine for cutting sheets to specified size.



FIG. 61. Wood-cellulose baled in water-proof packages ready for shipment. (Courtesy of Kijawa Mills.)

uniform moisture. Large laboratories must be available for this purpose and the Kipawa mill of the Canadian International Paper Company and the Brown Company of Berlin, N. H., have made a specialty in scientific control of the process.

4. *Finally comes the examination of the pulp produced:* The pulp must be analyzed for the various properties as required by the Rayon manufacturers. This involves a considerable amount of analytical work. Last but not least a concern manufacturing pulp for Rayon purposes must always keep itself posted on new developments. A scientifically trained staff and laboratories must be available for scientific research equipped with up-to-date scientific apparatus and other material required for studying the fundamentals of the pulping and Rayon process.

The two principal companies manufacturing a high grade Rayon alpha pulp in the American continent are the Kipawa Mills (Fig. 62) of the Canadian International Paper Company and the Brown Company Mills at Berlin, New Hampshire. The first produces about 100,000 tons a year of high-grade alpha pulp and the Brown Company produces at present about 30,000 tons annually. Their new plant built in 1926 will have an ultimate capacity of 60,000 tons annually, producing an alpha-cellulose variety which they guarantee to have an alpha-cellulose content of 94 per cent. In Europe, one of the principal Rayon wood-pulp manufacturing companies is the Uddeholms Aktiebolag, located at Uddeholms, Sweden.

Besides cellulose, wood pulp also contains resins, fats, hemicellulose, pentosans, lignin residues and mineral ash. The question of the suitability of wood pulp for Rayon production cannot be decided by a consideration of its chemical composition alone. But it is important to check it, for we know that if certain limits are exceeded the pulp is valueless for Rayon. Of course, not all Rayon processes are exactly

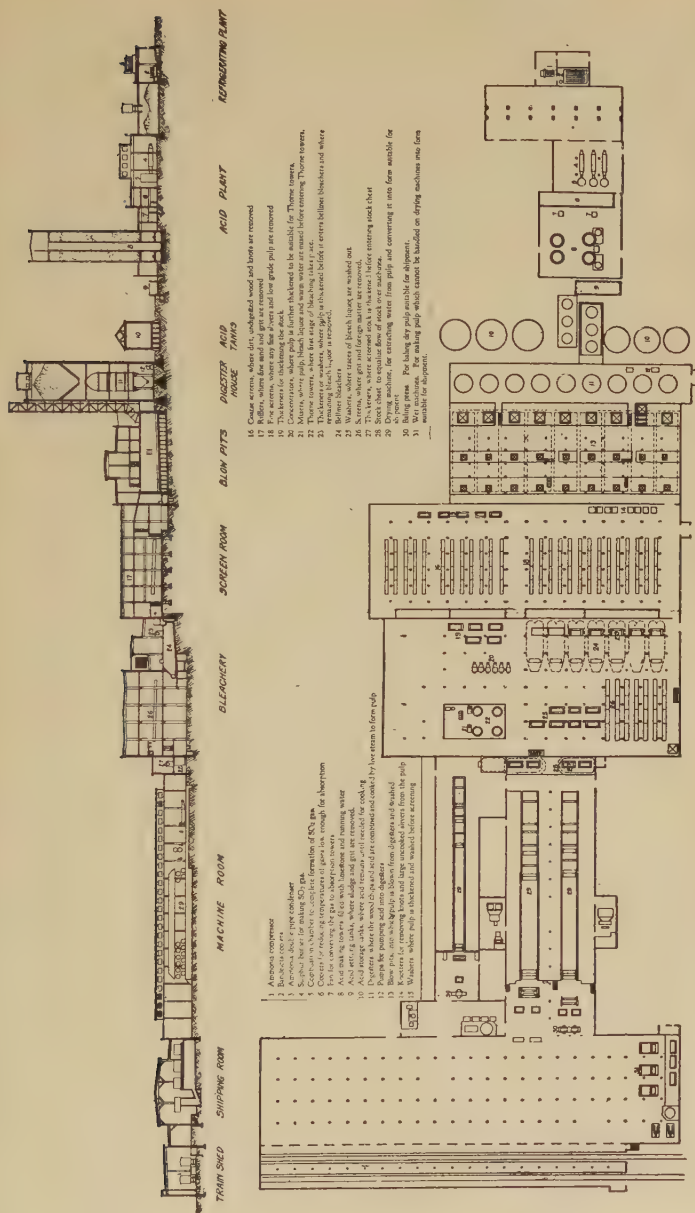


Fig. 62. Plan and Elevation of Kipawa Mills. (Courtesy of the International Paper and Pulp Company.)

alike and a wood pulp suitable for one modification might not be good for another. However, the following Table 86 gives the limit specifications set for wood pulp suitable for the production of Rayon:

TABLE 86.—RAYON WOOD-PULP SPECIFICATIONS

	Per Cent
<i>Alpha Cellulose</i> , the content of alkali resistant or alpha cellulose should approximate 90 per cent of the dry weight, and it should contain.....	Not under 90.0
<i>Beta Cellulose</i> , that is, cellulose soluble in alkali (hemicellulose) and reprecipitated by acetic acid under standard conditions; the remainder of the cellulose (also part of hemicellulose), that is.....	Not over 2.0
<i>Gamma Cellulose</i> is soluble in alkali and not precipitated by acetic acid, and together with other impurities shall be	Not over 4.0
<i>Ash Content.</i> If the ash content is over this specified amount it will cause obstruction of the minute holes of the spinnerets when the spinning operation is reached by precipitation of the calcium salts.....	Not over 0.3
<i>Resin.</i> The resin or the ether—soluble constituents should be.....	Not over 0.7
<i>Copper Number</i> , that is, the percentage of cuprous oxide, proportional to the percentage of oxy- and hydro-cellulose present, formed by reaction with a standard alkaline solution of cupric sulphate should be.....	Not over 3.0

The physical properties are important especially as to uniformity and capillarity since these have great bearing on how the chemicals are absorbed and the equality and balance with which the reactions will take place. The degree of molecular disturbances is also a vital consideration for the less the cellulose molecule has been broken down the better and more uniform the viscosity of solutions prepared from it will be. This accounts for the unsuitability of the harshly-treated

soda and sulphate pulps and the usability of the Rittner-Kellner's pulp whose treatment reactions are not so severe, and hence do not attack the cellulose molecule itself to so great a degree in the process of dissolving the incrustants.

It is customary for Rayon making companies to buy their wood pulp, from which point their problems to produce a high quality Rayon yarn begins. But one must consider that the preparation of the Rayon pulp from the log is an equally important, difficult and elaborate problem requiring the same degree of care in organizing the equipment and production, the same degree of plant development and investment.

It will not be long before either Rayon or pulp producing companies will organize themselves to contain within one single operating unit complete mills, starting with the logs from the forest and carrying the process through to Rayon yarn production. They will also have within themselves plants to manufacture the necessary chemical. In the Viscose process, for instance, caustic soda, carbon bisulphide and sulphuric acid will be manufactured. Power and steam plants and town sites will be developed and thus round out what will eventually be the most comprehensive industrial planning and operation, bound to lead to economy of production and the attainment of a high standard of Rayon yarn.

It will be such operations as these that will introduce the best and most complete laboratories guided by men of science in cellulose chemistry whose efforts and deductions will in due course obtain the results which René A. F. Réaumur predicted in 1754 when he made the famous prophecy that silk will be emulated by human artifice, which would some day set up a factory to do what the silk worm does.

A concentration of all necessary raw materials, chemicals and human effort and mind, all properly controlled to fixed and perfect standards—just as nature unerringly must be do-

ing in the case of the silk worm—is bound to recreate by human artifice real silk.

Cotton.—The cellulose obtained from cotton is the purest cellulose known in nature and it is ideal for the production of Rayon excepting that when compared to wood pulp it is too expensive if cotton hair is used.

Through the development of the cotton linter, however, the problem has been partially solved and this is the type of cotton (short staples) which is now employed for the making of Rayon. American cotton is 80 to 90 per cent cellulose and a smaller percentage is obtained from the Egyptian and Eastern cottons.

Cotton linters is being placed on the American market on a profitable basis due to the improvements in the ginning and the delinting machinery and the development of the cotton seed oil and oil-cake industry.

At the present time the Rayon cotton pulp is produced exclusively from linters which are obtained after the second ginning of the cotton seed in the cotton seed oil mills. This cotton represents the small hairs remaining after the removal of the (staple) cotton hairs from the seed. By careful delinting, cotton linters can be obtained fairly free from wood impurities, and before the linters are used for Rayon making wax, natural coloring matter and other impurities are extracted from the cotton by bleaching and the cellulose subsequently extracted with acids or alkalies.

Up to the present time the delinting of the cotton seed has produced fairly satisfactory results but new machinery is now being developed in Texas for which is predicted better results in delinting the cotton seed. It is claimed that it will remove twice the amount of cotton hairs, leaving the seed fairly clean and making it a better product for oil pressing.

The production of bleached linters pulp is carried out in the same way as paper making is, and pulp boards of the de-

sired size and thickness can thus be obtained. While the linters pulp can be prepared and also board sizes similar to the wood pulp, it is possible with modifications of the plant to use the linters pulp in the loose fibrous state.

The fact that the bleached linters have the power of quick absorption renders them particularly suitable for nitration and *acetylation* and for rapid solution in the cupra-ammonium re-agent. For this reason cotton linters are almost exclusively used for the production of nitro-cellulose, acetate and cupra-ammonium Rayon, which combined represent less than 20 per cent of the world's output of Rayon.

Flax, Cornstalks and Straw.—Other fibers from which cellulose, applicable for the production of Rayon, can be obtained are flax, cornstalks and straw. The flax represents a raw material of recent development in this industry. Sulphite wood pulp and cotton linters have been used for many years and the consumption of the spruce wood pulp is now so great that Rayon producers are casting around for new types of fibres from which high quality cellulose can be obtained for use in the near future; and considerable experimenting and development work is going on in Europe and the United States in connection with these fibers just mentioned and others which are under investigation.

There is no doubt that some of the other woods besides spruce, will be found in time useful for the production of Rayon when methods have been determined upon to so process these woods as to do away with the impurities which obtain in greater proportion in all other trees than is the case with spruce.

Chemicals.—The chemicals used, in various proportions, in the making of Rayon in the four processes are the following:

Acetic Acid
Ammonium Sulphate
Amyl Acetate
Benzyl Alcohol

Bicarbonate of Soda
Bleaching Powder
Butyl Acetate
Calcium Chloride

Carbon Bisulphide	Phosphates
Caustic Soda	Sizing Materials
Caustic Soda, Electrolytic	Soap, Textile
Caustic Soda, Liquor	Soap, Matseilles
Chlorine	Soda Ash
Di Acetin	Sodium Sulphate (Glauber's Salts)
Ethyl Acetate	Sodium Chloride
Glycerine	Sodium, Hypochlorite
Hydrochloric Acid	Sodium Peroxide
Hydrogen Peroxide	Solvents
Magnesium Sulphate	Starch Preserving Solution
(Epsom Salts)	Stamping Pastes
Mineral Salts	Sugar
Mono Acetin	Sulphur Di-Chloride
Nitric Acid	Sulphuryl Chloride
Oil, Conditioning	Sulphuric Acids
Oil, Sulphonated	Tannic Acid
Oil, Turkon	Thymol
Perborate of Soda	Triphenyl Phosphate
Plasticisers	Tri-Acetin

Water.—Water is, perhaps, one of the most important raw materials both for the Rayon producer and for the processor of Rayon yarns. For the Rayon producer, especially, an abundance of pure, clear, soft water, free from iron and manganese, is a prime requisite.

Water gathers up a load of impurities which it absorbs from the atmosphere, the soil through which it percolates, and the rocks over which it flows. Further, water changes depending on the volume of water flowing, the seasons of the year, etc. occur which make it desirable to set certain standards which water must have for any given process and then treat the water supply of the plant accordingly. Some waters are totally unfit for Rayon production and could not be gotten in to perfect condition except by methods which are too costly to consider.

Ground waters are usually clear because they are filtered in passing through the many layers of rocks, soil, sand, gravel, etc., but in this passage they, as a rule, absorb mineral matter so that a ground water usually has a greater amount of hardness than a surface water. However, the latter are usually

higher in suspended and coloring matters, both of which are objectionable to Rayon plants. It is, of course, impossible to obtain clear white skeins or very light shades if water contains color or turbidity. Water and its purification have been more fully discussed in the previous Chapter IX under "Rayon Engineering Problems."

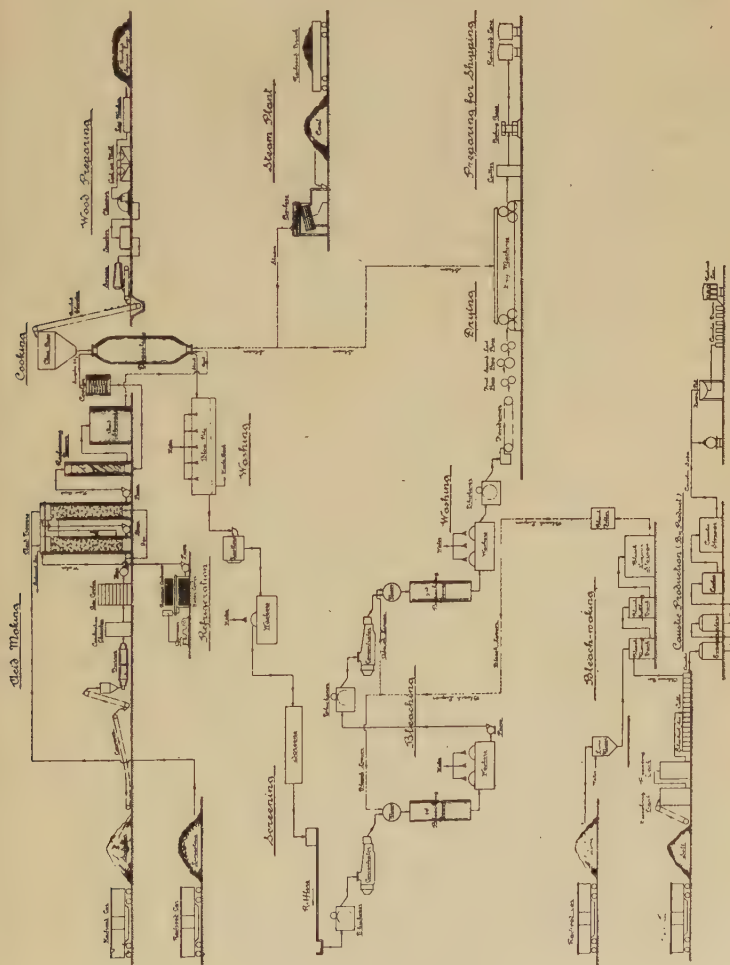


FIG. 62A. Flow Sheet for Alpha Cellulose production.

CHAPTER XI

VISCOSE PROCESS

HISTORY: The Viscose process had its greatest impetus, as a large and important industry, in England. The first method of producing Viscose solution was patented in 1892 by Cross, Bevan and Beadle (English patent No. 8700), their discovery being the result of a systematic investigation of cellulose which they have conducted from the year 1880 to the present time. The first spinning process was developed and patented by D. H. Stern (English Patents No. 1020 of 1898; No. 2529 of 1902; No. 7023 of 1903; and No. 16605 of 1903) who undertook the investigation of "spinning" Viscose solution for the Zurich Lamp Company. Then came C. F. Topham with his invention of the centrifugal spinning-pot (English patent No. 23,157 of 1900), which proved at once a radical development and a great step forward which led to the mass production of Viscose yarn.

The Viscose Syndicate, Ltd., which was formed in 1893 to develop the process of Cross and Bevan, joined with Stern after the latter's success in spinning Viscose solution, to form the Viscose Spinning Syndicate with a capital of only 4000 pounds. Topham who belonged to this group then came forth with his great invention of the centrifugal pot.

When in 1900 "Viscose Silk" (Rayon) became an accomplished fact, H. G. Tetley of Samuel Courtaulds & Company with his associate Thomas Latham, realizing the future of the process, proceeded to establish the enterprise on a firm basis, as a result of which Courtaulds commenced production

of Rayon on a commercial scale in the year 1905 at their Coventry plant.

Viscose Rayon owes its name to the viscous solution from which it is made. The Viscose process is at present the most widely used of the four Rayon manufacturing methods, about 85 per cent of the world's Rayon production being by the Viscose process. The chief advantage of the process, however, is in its simplicity and low cost.

The principal considerations in carrying out the Viscose process are first:

- (a) The raw materials.
- (b) The plant process.

The plant process must be analyzed from the following three angles:

- (1) The chemical plant which prepares the Viscose solution.
- (2) The spinning of the Viscose solution.
- (3) The finishing or preparation of the yarn for the user.

A. THE RAW MATERIALS

The principal materials used in this process are: Wood Pulp, a bleached Sulphite Pulp, supplied to the Rayon plant in the form of bleached sheets, Sodium Hydroxide or Caustic Soda, Carbon Disulphide and Sulphuric Acid.

The essential characteristics of the raw materials used in the production of Viscose Rayon are more fully described in the following:

Wood Pulp.—Wood pulp has in the past been the most favored raw material for the Viscose process. To a large extent this still holds true, but large quantities of cotton linters are now used, together with wood pulp. The most suitable wood pulp for use in Rayon manufacture is that made from pinaceous trees by the bisulphite method. It should

show a low percentage of resinous matter and ash, should be entirely free from chlorine, of low copper number, and high in alpha-cellulose. Wood pulp suitable for making Rayon by the Viscose process should be uniform in both chemical analysis and physical characteristics. This uniformity can only be obtained by:

- (a) Adequate supply of uniform wood.
- (b) Special mill design and equipment.
- (c) Complete technical control of pulp mill operations.

The importance of adequate supplies of uniform wood cannot be overestimated. Spruce grown in extreme northern latitudes where growth is slow, yielding dense, uniform wood is most desirable, but selection of the right species of spruce, even when grown under these conditions, is essential.

The wood pulp originally used for the manufacture of Viscose in the United States was imported from Sweden and large quantities are still imported from this country, as well as from Norway and Canada. Large quantities of pulp are also manufactured in the United States. The United States Tariff Commission Survey states that two large producers of Rayon in America prefer domestic and Canadian wood pulp, while a third prefers Scandinavian. The Riordan Pulp Corporation of Canada produced pulp for the Viscose process in 1908 from spruce trees about one hundred years old and 10 inches in diameter at the butt. This company has recently built some very modern Rayon pulp mills and supplies virtually half of the total quantity required for this purpose, amounting to 100,000 tons per annum. The Brown Company of Berlin, N. H., is one of the most important American Rayon pulp manufacturers. This company supplies a high grade of alpha-cellulose pulp, and with the new mill built in 1926, will soon have a production of 60,000 tons annually.

Since the pulp is the basic material of the whole process,

great care must be exercised in securing the correct grade because the quality of the Rayon yarn depends in a large measure upon the characteristics of the pulp.

Theoretically, the quantity of pulp required for 100 pounds of salable Rayon is 150 pounds and it is estimated that the Rayon industry in the United States consumed over 100,000,000 pounds of wood pulp in 1927. The problem of securing a steady supply of this raw material in the future is facing every large Rayon producer. To insure this, a close cooperation between the Rayon maker and the pulp manufacturer will be necessary. We shall perhaps see Rayon producers in a combination of some sort with pulp manufacturers, perhaps in a direct merger or a working agreement. In fact, plans have already been undertaken for a combined pulp and Rayon plant on the Pacific coast of Canada.

Research work is steadily going on to find some way of widening the scope of available cellulose. The physical and chemical and other characteristics of wood pulp are more fully discussed in the following article by Professor Emil Heuser:

WOOD PULP IN THE VISCOSE PROCESS¹

"In addition to the use of cotton linters by the cuprammonium process, the use of wood pulp by the Viscose process must be regarded as an extremely important advance. The kind of pulp employed is sulphite, other pulps have not proved so serviceable; probably this lies less in the chemical composition—though pentosanes and hexosanes may act favorably—than in the physical constitution of the fibres. The deeper reasons for this fact, however, are still unknown. So far we are not in a position to form an absolutely correct judgment as to the value of a particular pulp—why one pulp is suitable and another not. The pulp under investigation can fulfill the ordinary conditions, afford satisfactory analytical data and yet it can be manufactured with

¹ From an article by Prof. Emil Heuser (translated by Dr. Paul Barthelow). From *American Dyestuff Reporter*, Oct. 9, 1925 issue.

poor results. It follows that we are unable to see deeply enough into the constitution of cellulose which apparently has properties the secret of which is still hidden.

"The pulp, however, should have certain qualities; it should contain no degradation products of wood and no amounts of hydrocellulose nor oxycellulose. The copper number should be as small as possible. The number 2 may be regarded as the limit. Further, the pulp should contain as small amounts of substances soluble in alkalis as possible. These are mostly described under the name 'hemicellulose.' To this group belong not merely the pentosanes and hexosanes; rather, the greater portion of the alkali soluble substances belong to the pulp itself.

"Supposing, for example, that 14 per cent of sulphite pulp dissolves in 17 per cent soda liquor, then in the best circumstances half consists of pentosanes and hexosanes, while the other half is cellulose. With a copper number of 2 not much hydrocellulose or oxycellulose is present. The pulp itself has become soluble in alkalis and this solubility is due to a physical change, depolymerization, a reduction in the size of the cellulose molecules. We can artificially increase this depolymerization to such a point that all the cellulose, consequently the entire pulp, is soluble in alkali. This gives us occasion for the view that depolymerization in the manufacture of pulp chiefly occurs during the cooking process, giving us a certain degree of power to regulate the depolymerization.

"Obviously the constitution of the wood is of great importance, and here, in spite of the investigations of Wahlberg, Sieber, Bergman and others, we are to some extent still groping in darkness. The rate of growth, the thickness or density of the wood substances, whether young or old trees—these and many other factors determine the physical constitution of the pulp; and these and the conditions of cooking, and finally, those of bleaching determine the alpha-cellulose of the pulp. In this connection it is well known that the Norwegian pulp in general contains the highest proportion of alpha-cellulose, next the Swedish and then the German, but why the Norwegian gives the best number I cannot tell."

Caustic Soda.—The amount of caustic soda (NaOH) required in a Rayon plant is considerable. Approximately 2 tons of caustic soda are needed for every ton of salable Rayon. The caustic used must be of a very high quality and low in sodium carbonate, chloride and iron. Several caustic soda manufacturers make a specialty of furnishing a suitable product. The following is a typical analysis of solid 76 per cent soda, the product of one of these manufacturers.

	<i>Per cent</i>
Actual Alkali Na_2O	76.42
Alkali, N. Y. and L. test	78.87
Sodium Hydroxide	97.87
Sodium Carbonate	0.96
Sodium Chloride	0.53
Sodium Sulphate	0.23

It is estimated that 35,000 tons of caustic were consumed in 1924 by the Rayon industry, 49,500 tons in 1925, 67,000 tons in 1926 and 75,000 tons in 1927. It is interesting to note that Rayon makers consume almost 10 per cent of all caustic soda produced. The caustic is used in two different forms, solid 76 per cent and liquid. The liquid is furnished either in 25 per cent or 50 per cent strength. The solid is usually shipped in iron drums weighing 760 pounds each. Tank cars are used to carry the liquid caustic. While it is claimed that the liquid caustic is slightly higher in quality than the solid, its general adoption is unlikely for it contains too large a percentage of water and unless the Rayon plant is very favorably located this large amount of water means considerable extra freight.

Carbon Disulphide.—The next important raw material required for Viscose Rayon is carbon disulphide. Like all other raw materials for this industry, the requirements as to quality are quite severe. Several American manufacturers have specialized in furnishing a suitable product and are producing a

material free from sulphur and hydrogen sulphide which meets the requirements of the Rayon maker. The approximate amount of carbon disulphide required to make 1 ton of Rayon is 1200 pounds.

Sulphuric Acid.—To make 1 ton of salable Rayon, $1\frac{1}{2}$ tons of 66-degree Baumé sulphuric acid are required. A high quality of water-white acid is used. Compared with the total quantity of sulphuric acid produced in this country, the amount used in making Rayon is relatively small, although no figures are available for comparison.

The qualities of the principal materials used per thousand pounds of Rayon are summarized as follows:

	<i>Pounds</i>
(1) Alpha-cellulose Sulphite pulp ...	1,500
(2) Caustic Soda	2,000
(3) Carbon Disulphide	600
(4) Sulphuric Acid, 66-degree	1,500

Other Chemicals.—The other chemicals used in the production of Viscose Rayon are not of the importance of those first mentioned. In each case uniform quality is insisted upon and the standards set are high. It may be repeated here that one of the reasons for the wide adoption and application of the Viscose process is due to the kind of raw materials used. Comparatively speaking, they are very cheap in price and are available in quantity in almost every part of the world. Because of this comparative cheapness there is no necessity of an expensive recovery system with its added technical difficulties, such as is the case with the other processes.

There is, of course, a possibility of recovering a certain percentage of the materials used in the Viscose process, such as Carbon Disulphide and Caustic Soda, but it is not an actual problem that must be solved before the process is feasible. Rather, it is a possibility of still further adding to the advan-

tage of cost which this process already possesses. It may be mentioned that several processes have been developed for the recovery of the Caustic Soda solution, Carbon Disulphide and the spent Sulphuric Acid spinning bath, which are discussed in Chapter XV on Recovery of Chemicals.

What the actual value of these recovery processes may be is difficult to estimate at this time. Increasing production may bring the Rayon industry to a point where competition may be so keen, or some radical and unforeseen development may give advantage to some other process, that a well-worked-out recovery system will prove a most valuable asset to any Viscose company possessing it. This phase is not being overlooked and is receiving its share of the attention now being given to research on the manufacture of Viscose.

B. THE PLANT PROCESS

1. *The Chemical Plant for Preparing Viscose Solution*

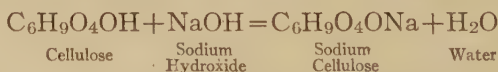
First Step: Preparation. While cotton linters are used to some extent as a base in the manufacture of Rayon by the Viscose process, wood pulp is mostly used. The cotton linters must be degreased and bleached. Wood pulp is usually received in bales containing large sheets ready for the first operation. Samples of these sheets are analyzed in order to insure that the pulp meets specifications.

Sometimes, however, the pulp sheets as received are not of proper size for use in the steeping tank and may not be of proper moisture content. When such is the case a drying operation may be required to bring the moisture content to the correct percentage. In this drying operation, the pulp is placed in a room fitted with steam coils or some other heating device. Care is taken to see that the pulp is so placed that the warm air is uniformly distributed to all the sheets. After

the proper degree of moisture has been attained, which must not exceed 10 per cent, the sheets of pulp are removed and sent to a cutting machine or guillotine, which cuts them to a size to fit the steeping press tank. The usual type of board cutter is used for this purpose.

Second Step: The Steeping or Mercerizing Process. The first manufacturing step is the soaking of the pulp sheets in a caustic soda solution, which solution is approximately 18 per cent strength. The steeping operation must be carried out so that the impregnation of the pulp with the caustic soda solution is as nearly uniform as possible throughout the entire batch. In this operation the pulp combines with the caustic soda to form sodium cellulose. After the impregnation is complete the excess of caustic solution is removed by squeezing the sheets, usually in the steeping tank or press.

The reaction at this stage is of the type shown below, which probably represents one of the main reactions between cellulose and caustic soda, in the presence of an excess of the soda. In this reaction the cellulose combines with the caustic soda (sodium hydroxide) to produce a compound known as sodium cellulose, probably as shown in the equation:



As the hemicellulose content of the original pulp is soluble in the caustic soda soaking solution, these soluble celluloses are largely removed from the sodium cellulose, along with the excess of caustic solution, in the squeezing operation following the actual soaking. If the hemicellulose content of the original pulp was sufficiently low, the amount of this soluble cellulose in the waste caustic soda solution will be less than 1 to 1.5 per cent, in which case this waste solution can be used again, after strengthening it by the addition of 40 to 45 per cent of fresh caustic soda solution, to treat further

pulp. An excess of the soluble celluloses (hemicellulose) in the caustic solution is harmful to the Viscose solution and the Rayon yarn produced, so that careful control of this factor in the caustic soda solution is essential.

The time required for soaking the cellulose sheets, that is the formation of sodium cellulose, largely depends upon the speed of penetration of caustic soda solution into the sheets. It is absolutely essential that every portion of the cellulose receive a uniform treatment. As usually conducted, the soaking operation requires from 2 to 4 hours, the temperature varying in different plants between 56 and 62 degrees Fahr. This temperature is generally controlled to within 2 degrees Fahr. in any one plant. It is claimed that by soaking the sheets under vacuum, as described in Dreaper's English patent No. 178,152, the time may be reduced by 25 per cent.

The handling of the caustic soaked sodium cellulose sheets has always been a troublesome and difficult task. Because of these difficulties, several methods have been devised to overcome the objectionable features. Among those is a press that combines both steeping tank and press. The sheets of pulp, approximately 100 in number, are placed vertically in the tank part of the machine between perforated iron plates, Figs. 63 and 64, the caustic (sodium hydroxide) solution is run in, and after the soaking has been completed, the caustic soda solution is drained off, the platen of the press is forced for-



FIG. 63. Steeping Hydraulic Press with intermediate solid plates and tank.
(Courtesy, The Hydraulic Press Mfg. Co.)

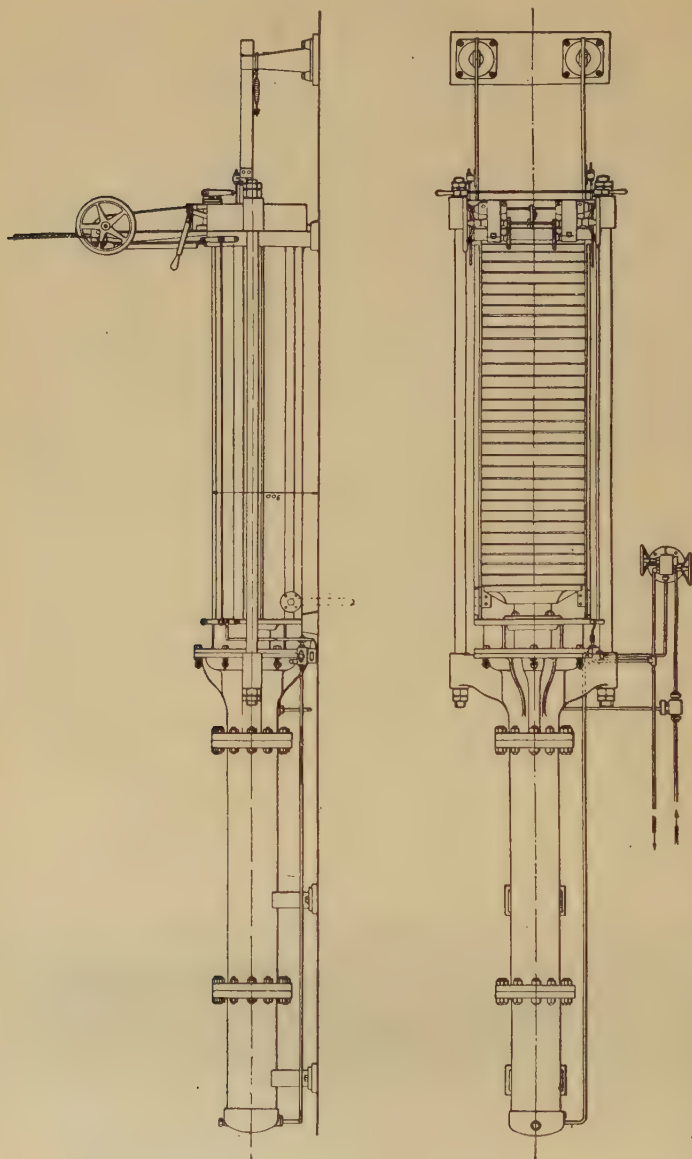


FIG. 64. Hydraulic-Horizontal combined steeping Press. (Courtesy Ezio Pensotti, Milan.)

ward, and the soaked sheets pressed to about 3 times their original weight; thus a charge of 200 pounds of pulp steeped in 300 gallons of 17.5 per cent caustic soda solution is reduced by pressure to about 600 pounds. After pressing the pulp is carried forward to an opening in the bottom of the press and dropped through this opening direct to the shredders or to a wagon or small car, thence to the weighing scales and finally to the shredders.

The Third Step: Shredding. In order to thoroughly mix the sodium cellulose, to aid in aging it, as well as in its further treatment and subsequent solution, the sheets of sodium cellulose, "alkali cellulose" or "soda cellulose" are shedded after the soaking and pressing operations. In this operation, which is usually carried out in a machine called a shredder or disintegrator, the sheets are reduced to very finely divided white flock particles, commonly called "crumbs." These shredders contain a pair of blades which carry on their faces sets of serrated shoes. The bottom of the trough of this machine curves to form two half cylinders, at the junction of which is inserted a serrated saddle. The passing of the sharp teeth on the revolving blades across the teeth of the saddle shreds the cellulose up into fluffy, snow-white crumbs. A cooling jacket, cast integral with the trough shell, carries off the heat generated and holds the temperature constant. (See Figs. 65 and 66.)

The usual batch handled in one of these shredding machines is the equivalent of 200 pounds of dry pulp, the same amount as that handled in the steeping press. Shredders have been made for double this amount but they are not found in general use. The time required for the shredding operation is from 2 to 3 hours and one machine will usually take care of 8 batches during the 24-hour working day. When the shredding is complete the crumbs are discharged and placed in aging cans.

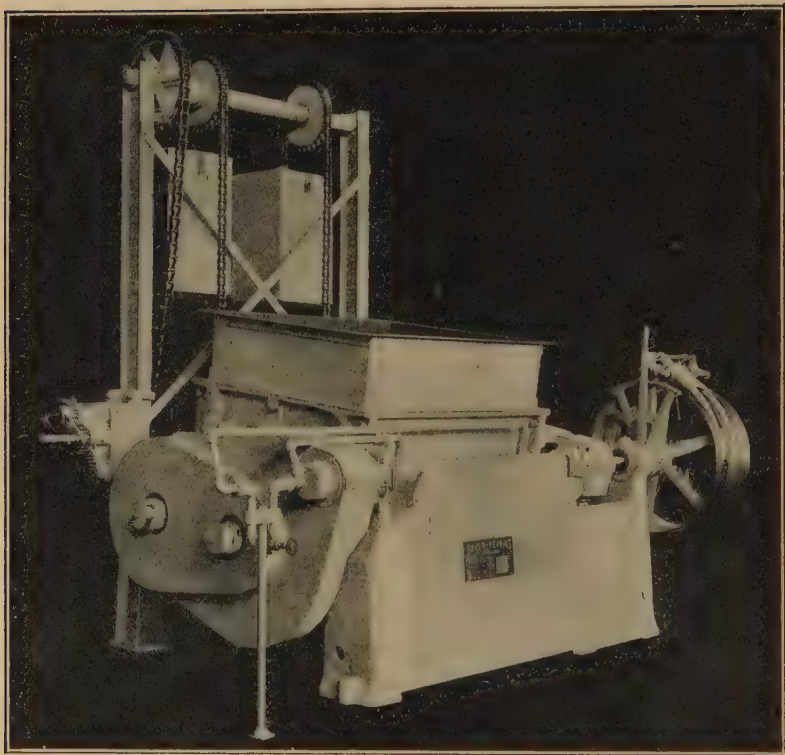


FIG. 65. Shredding Machine. (Courtesy of Baker-Perkins Co.)

The Fourth Step: Aging or Maturing of the Alkali Cellulose Crumbs. The shredded alkali cellulose crumbs are aged by packing them in closed cylindrical or rectangular cans made of either sheet steel or iron, of about 10 gallons capacity. These cans are kept closed and are stored at a closely controlled temperature, usually about 75 degrees Fahr., for from 48 to 72 hours. (See Fig. 67.) During this aging process certain changes occur which are not as yet fully understood. It appears that certain changes take place within the cellulose molecule and it may be possible that some oxidation also takes

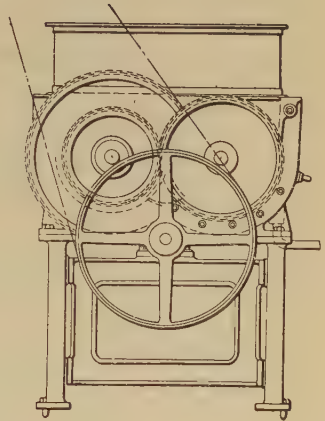
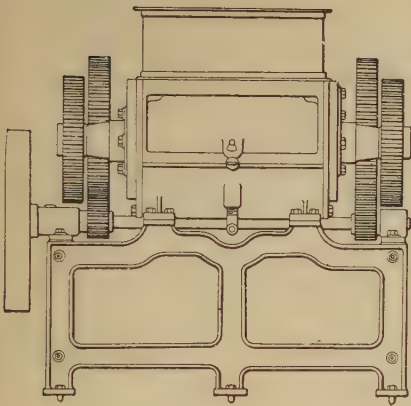
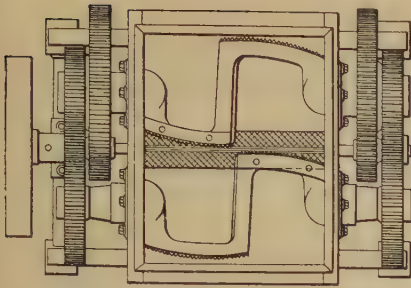


FIG. 66. Shredder. (Ezio Pensotti.)

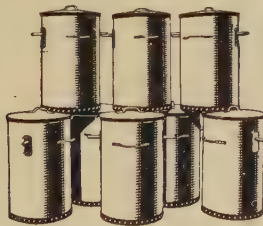


FIG. 67. Crumb Aging Cans. (Pirna.)

place. It is, however, a very important step in the preparation of a spinning solution with the proper characteristics.

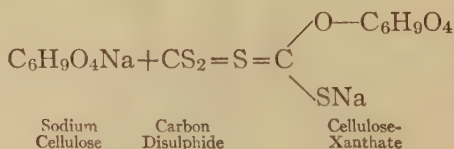
Both the length of time and temperature of the aging

process are very important, as with an increase in either of these factors, the viscosity of the spinning solution is reduced, probably due to increased degradation or depolymerization of the cellulose.

During aging of the alkali-cellulose, oxygen in small amounts is absorbed from the air or from active materials, such as sodium peroxide, which may be added to the liquor. Only a small quantity of sodium peroxide is permissible hence the amount added must be carefully controlled. The character of the pulp employed and the spinning operation to be used, also have an effect on the determination of these factors. Once the time schedule for aging has been determined and the temperature-maximum and minimum established, no variations from these standards are permitted.

The Fifth Step: Mixing Cellulose with Carbon Disulphide or "Xanthating." In this step the alkali-cellulose crumbs, now aged to the desired degree, are brought into contact with carbon disulphide to form the gelatinous mass known as cellulose-xanthate.

The reaction of carbon disulphide with the alkali cellulose produces the sodium salt of cellulose xanthogenic acid, or sodium cellulose xanthate, which is usually called cellulose, xanthate. This reaction probably occurs according to the following equation:



In actual commercial practice the quantities used correspond to 1.5 molecules of $\text{C}_6\text{H}_{10}\text{O}_5$ (cellulose) to 1 molecule of CS_2 (carbon disulphide). This operation is carried out in a machine called a xanthator, a barratte, or a sulphidizing drum.

Two types of xanthating machines are in general use, one cylindrical and the other hexagonal, made of iron, though nickel plated drums are preferable since nickel is scarcely

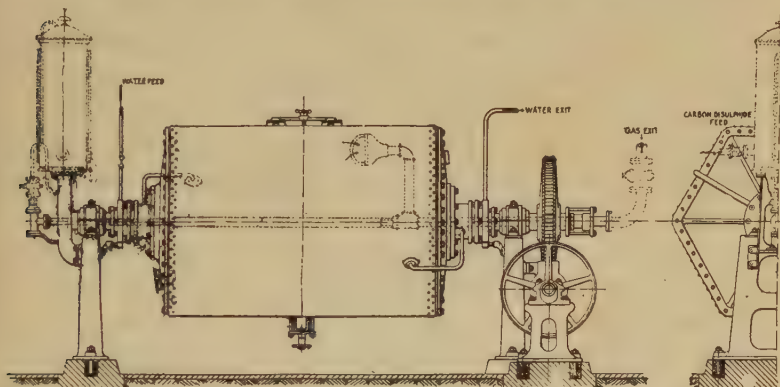


FIG. 68. Xanthating Drum Elevation. (Courtesy of Ezio Pensotti, Milano.)

attacked by alkali. In both Figures 68 and 69 the carbon disulphide reservoir and feed pipe are shown.

The crumbs from the aging cans are dumped into the xanthator, a measured amount of carbon disulphide is ad-

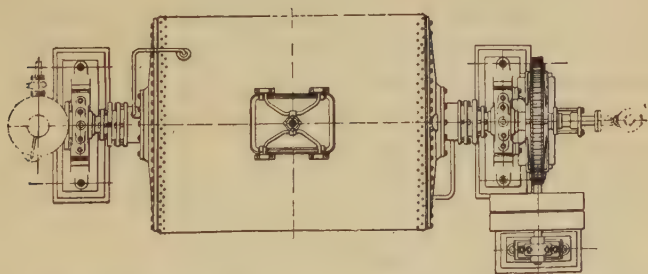


FIG. 69. Xanthating Drum Plan View. (Courtesy of Ezio Pensotti, Milano.)

mitted, and the xanthator rotated for about three hours until the operation is completed. There are no moving parts in the xanthator to act as agitators, the mixing being accom-

plished only by the revolving motion of the drum. During the xanthating operation the color of the crumbs changes from white through yellow and finally to a characteristic orange-red color when the operation is stopped. Formation of hard lumps during this process must be avoided, else these lumps will cause trouble in the succeeding operations. Careful control of time and temperature, which must not be allowed to rise above 85 degrees Fahr., the proper amount of carbon disulphide, as well as several other factors all play an important part in the making of a proper cellulose-xanthate.

When the xanthate has reached the desired point the excess gas remaining in the drum is exhausted by vacuum and the cellulose-xanthate is dumped. The xanthators are usually double-jacketed to permit circulation of a cooling medium in order to remove the heat generated during the chemical changes and to maintain a uniform temperature. They are usually built to handle 200 pounds of original pulp, which is the same amount as that handled in one shredder charge. The xanthating operation is not without certain dangers as the liquid is highly inflammable and the necessary precautions must be observed. No exposed iron pipes for superheated steam or motors should be in the carbon disulphide rooms. Due to the high inductive capacity of carbon disulphide, it is important to earth all vessels containing large quantities of this liquid. To insure the safety of employees and equipment all safeguards must be enforced.

VISCOSE SPINNING SOLUTION: At this point the preparation of the Viscose Spinning solution begins.

The Sixth Step: Xanthate to Viscose Mixing. In order to prepare the spinning solution the cellulose-xanthate is dumped through a chute into a vertical or horizontal iron-jacketed mixer as shown in Figs. 70, 71 and 72. A dilute solution of caustic soda and water is added and the mass is agitated until a proper homogeneous mixture of Viscose containing about 61 per cent

of cellulose and 8 per cent of alkali, figured as caustic soda, has been obtained. The mixing should take from 4 to 5 hours with the solution held at a temperature below 60 degrees Fahr. For this operation mixing vessels of several types are used. These mixers have agitating arms so designed as to bring the whole mass to a thorough and homogeneous mixture.

In Europe it has been the practice in some plants to use grinding machines in order to prevent hard lumps from forming in the solution. Sometimes these grinding machines are



FIG. 70.

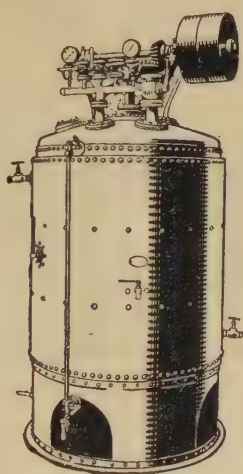


FIG. 71.

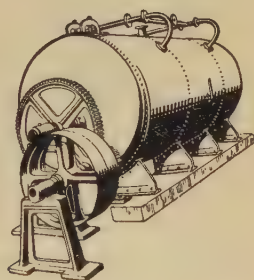


FIG. 72.

Viscose Solution Mixers. (Pirna).

incorporated in the mixers and in other cases they are separate machines. So far as is known these grinding devices are not used in the United States. Proper selection of materials, with exact control of time and temperature, result in an absence of lumps and give a spinning solution of the proper characteristics.

The Seventh Step: Blending. Upon completion of the mixing operation several mixer batches are run into a large

mixer for the purpose of blending them into one uniform batch or spinning charge. This operation insures a more thoroughly blended mass and is an aid toward securing all the qualities necessary to the spinning operation. The size or quantity of this charge depends upon several factors, chief among which are the time of the spinning cycle and the make-up of the neutralizing bath.

Eighth Step: Ripening. The Viscose solution is now ready for an aging process, somewhat similar to that in which the crumbs are aged, but which is called "ripening." The Viscose solution is sucked or blown from the mixers into the ripening tanks, as shown in Fig. 73, which are usually located

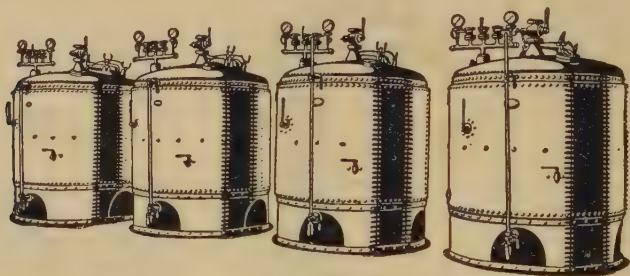


FIG. 73. Aging Tanks. (Pirna.)

in a cellar or other special room which is well provided with thermal insulation. The exact changes occurring in the solution during the ripening process are not well understood, but it is well known that with time, some xanthic acid splits off and the "molecule" contains a larger proportion of cellulose. It is, of course, understood that the Viscose is in a colloidal condition during this ripening process and, very probably, as the chemical changes take place, there are also changes in the colloidal particles.

The fresh Viscose solution from the blending process usually contains about 2.5 per cent of combined sulphur but as the xanthic acid splits off from the cellulose portion of the

Viscose, this combined sulphur is gradually decreased to about 1.0 per cent, the remaining sulphur being present as sulphur by-products. With the decrease in the sulphur content of the Viscose, there is also a decrease in solubility and, if the ripening is too great, coagulation occurs.

The entire ripening process requires very critical control, as the temperature factor is extremely delicate; 1 or 2 degrees increase in temperature during the aging being equal to 8 or 10 hours more time in the process. Therefore, both time and temperature are extremely important factors. As is usual for most steps in the Viscose process, each plant has its own procedure in ripening. As a rule the temperature is held at between 50 to 68 degrees Fahr. and the usual time is 4 to 5 days, or even longer. During the ripening process, the changes in the solution are followed just as closely as possible by means of both chemical and physical tests.

Ninth Step: Filtration. During the ripening process it is usual to filter the Viscose solution. This is done by forcing the solution, by pressure and/or vacuum from one ripening tank to another. This filtration is an exceedingly important step in the process and it is here that the purity of the water used in the process becomes important. It is absolutely necessary that this filtration remove all solid matter from the Viscose solution, in order to prevent clogging the minute holes in the spinnerets. Usually any lime salts present in the water used in the Viscose process very considerably increase the filtration difficulties. It is not unusual to at least partially de-aerate the Viscose solution during the ripening process also.

Various types of filter presses are employed for this filtration. In some cases the solution is passed through presses containing cotton wool, confined between layers of coarsely woven cloth. Again, the solution receives three filtrations, the first through cotton wool and the second and third through finely woven or knit cloth. Usually every precaution is taken

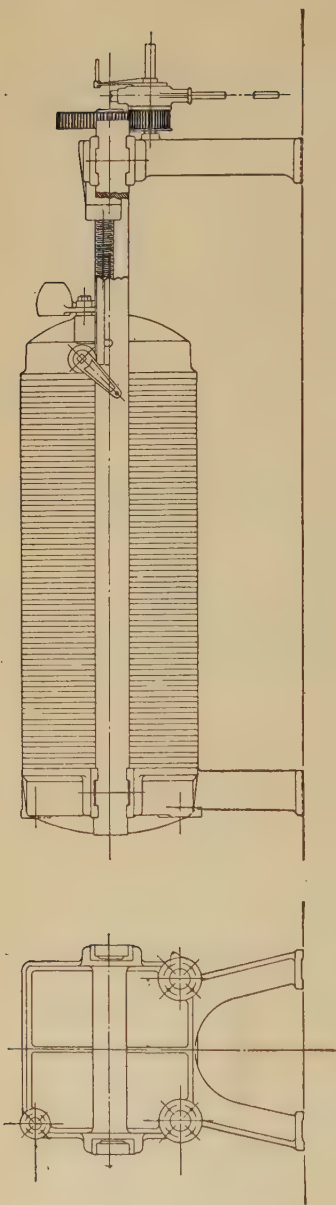


FIG. 74. High Pressure Filter Press. (Courtesy of John Johnson Corp.)

to prevent air from entering the Viscose solution during the ripening and, therefore, the filtration, but processes have been patented in which air, oxygen, or oxidizing substances were added to the solution during the ripening process. See Fig. 74.

The Tenth Step: De-Aeration. After ripening, but before the solution is ready for spinning, the air bubbles must be removed. Unless removed these air bubbles will cause breakage of the filaments at the spinnerets. To accomplish this the solution is run into tanks and vacuum is applied for at least twenty-four hours. Following the removal of the bubbles the solution is ready for spinning.

Many variations occur in the different plants in the preparation of the Viscose solution. These originate in the character, grade and quality of the raw materials used, including the chemicals; the amounts of chemicals used; the temperature at which each operation is conducted, as well as the time given; etc. Each

plant develops its own schedule of operations, based upon its own methods of procedure and processes and these are held secret by those in charge of the plant.

Coagulating or Spinning Bath Preparation

The Eleventh Step: The Viscose solution is now ready for conversion into filaments by the so-called "spinning" operation. In this connection it is first forced into the main pipe line (h) leading to the spinning machine (see Fig. 75). This line branches off to the many spinning machines, and eventually terminates in the platinum or other alloy spinnerets (g), each of which contains numerous small holes through which the Viscose solution must pass into the coagulating or spinning bath to form the regenerated cellulose filaments.

The usual spinning bath used for the purpose of hardening the Viscose solution into threads is a solution of sulphuric acid, of between 10 and 11 per cent by volume, and containing some suitable salt, such as nitre cake (sodium sulphate). Many other materials have been tried for the coagulating bath; some of them are patented and others are carefully guarded secrets. A few materials which have been used are starch, sugar, glucose, sodium sulphite, etc., all in combination with either sulphuric acid or some other acid which will bring about the required reaction. The control of the spinning bath must be very positive and both acid and salt content held within definite fixed limits. The temperature must also be held at the required degree and the flow through the spinning machine troughs maintained at the proper rate.

To make up the spinning bath the sulphuric acid is blown from a large storage tank by means of compressed air, or as in some cases, by means of pumps; the acid is sent to a measuring tank and thence the proper amount is sent to the make-up tanks. Two or more make-up tanks are employed. Since the acid is at a concentration which is highly active, lead-

lined tanks must be used. To these make-up tanks is returned the spent spinning bath from the spinning machines and the proper amount of fresh acid is added to bring the acid content back to proper strength. An amount of sodium sulphate is also dumped in to bring the salt content back to normal. On an upper level are other holding tanks and a constant circulation is maintained from the make-up tanks to the holding tanks which, of course, must also be lead-lined. The pumps for this purpose must be lead-lined. Coils within the tanks, equipped with temperature controllers, maintain the constant temperature required. From the upper level holding tanks the spinning bath flows by gravity to the spinning machines, through the troughs (see (a) Fig. 75), and then back to the make-up tanks to be brought back to strength again.

It is important that the coagulating bath be of such composition as to solidify the Viscose solution instantly as it passes through the spinneret holes, and give sufficient strength to these quickly regenerated threads so that they can be carried further in the operation of winding without strain or breakage.

The experiments for the development of a reliable spinning bath were long and tedious, and this question cannot be considered at an end, as many investigators are still studying the problem, with a view to further improvements.

The combined bath of sulphuric acid and sodium sulphate, together with zinc or ammonium salts, is the result of experiments which superseded more troublesome methods. The addition of carbohydrates to the finally adopted coagulating bath has the effect of preventing the salts from crystallizing which later add difficulty in reeling the threads; this addition of carbohydrates also gives strength to the thread and improves its covering power.

Many compositions or formulas for coagulating baths have been suggested and patented but very few are really known

to be more effective than the one presented in the previous paragraph. Other factors besides the compositions of the bath have a decided effect upon the thread produced. These factors are:

- (1) The temperature of the bath, which should be approximately 85 degrees Fahr.
- (2) The length of immersion of the filament, which can vary from 1 inch to 10 inches, or even more.
- (3) The rate at which the filament is produced, which can vary from 130 to 200 feet per minute.

Any of the above three factors can be varied, with the result that different qualities of Rayon filament will be obtained and no two plants have exactly the same combination of the above factors nor the same compositions of the coagulating bath. The following are some of the patented bath compositions:

- (1)* 8% Sulphuric Acid
 17.5% Ammonium Sulphate Courtauld's and Wilson
 7.5% Glucose English Patent 5595 of
 67% Water and Sodium Sulphate 1908
- (2)* 8% Sulphuric Acid
 10% Glucose Courtauld's and Wilson
 12% Sodium Sulphate English patent 406 of
 1% Zinc Sulphate 1911
 69% Water
- (3)* 10% Sulphuric Acid Courtauld's and Wilson
 30% Glucose English Patent 21,405 of
 60% Water and Sodium Sulphate 1907

The character of the Viscose filament depends to a considerable extent on the nature of the precipitating bath hence

* See E. Wheeler, "Manufacture of Artificial Silk."

this must not be ignored when introducing any changes in the composition of the bath. So many patents have been obtained on such slight variations in the bath that it often leads one to suppose that these patents are questionable in their real value, though proving material for royalties.

The Spinning of the Viscose Solution

The Twelfth Step: In the spinning operation the cellulose contained in the Viscose spinning solution is converted into endless filaments. This change is accomplished by means of the neutralizing bath. The spinning bath, being acid, neutralizes the alkali solvent in the spinning solution, leaving the regenerated cellulose in the form of threads. These threads are strong enough to be handled through the succeeding steps of the process.

The two methods generally in use differ in the mechanical handling only, the chemistry being practically the same in each. These methods are:

- (1) The bobbin or parallel spinning method.
- (2) The pot or centrifugal spinning method.

The Spinning Machine.—The two methods of spinning Viscose solution are carried out by practically the same type of machine, except in the bobbin method the filaments are wound untwisted on a bobbin rendering it necessary to twist these threads on another machine later in the process. In the pot or centrifugal spinning machine the filaments, collected into one thread, are taken up centrifugally around the inside periphery of a metal box, revolving at high speed, giving a twist to the thread at the same time.

The scheme of the bobbin method is indicated in Fig. 75, which illustrates a bobbin Spinning Machine.

In the drawing, (a) is the trough which carries, throughout the entire length of the spinning machine, the coagulating or

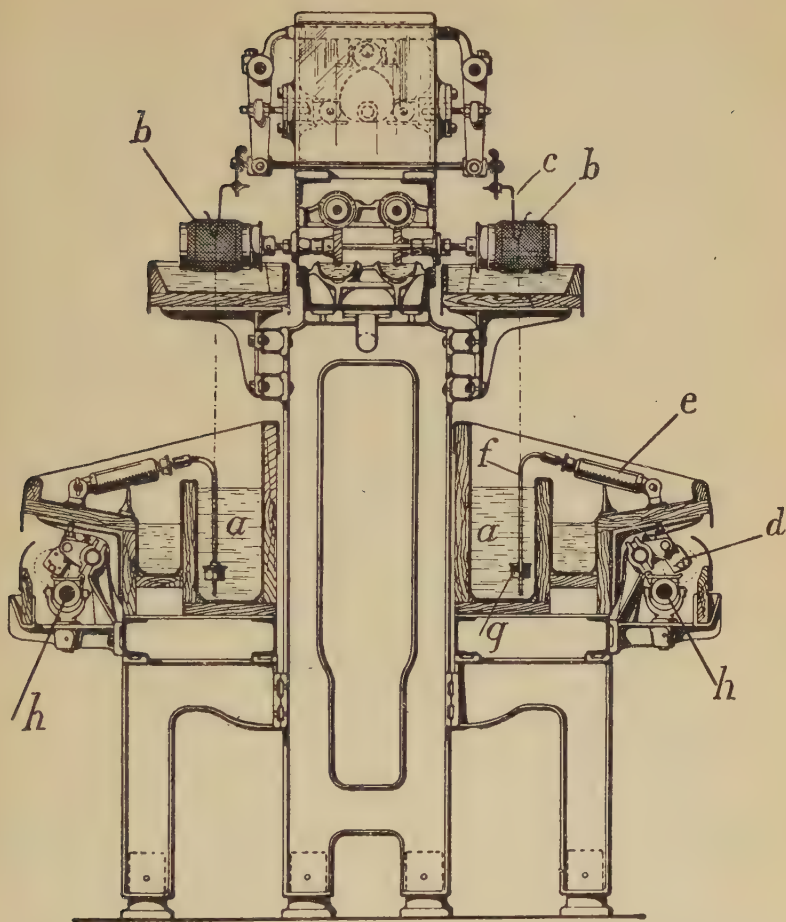


FIG. 75. Bobbin Spinning Machine. (C. G. Haubold A. G., Chemnitz, Germany.)

neutralizing bath; (b) is the bobbin upon which the thread, made up of one or more filaments, is wound untwisted and carried across the bobbin from one end to the other by the hook (c); the special pump, (d) (one for each spinneret), forces the Viscose solution (just enough to produce per unit

of time a certain length of thread of a fixed denier) to and through the candle filter, (*e*) which filters for the last time the Viscose solution before passing through the glass goose neck (*f*) to and through the spinneret or jet (*g*) into the coagulating bath (*a*) and thence to the glass or metal bobbin (*b*).

The scheme of the Centrifugal method is shown by following the lettering of Fig. 76, which represents an illustration of a centrifugal pot spinning machine:

In Fig. 76, showing a section through the spinning unit or head, of which there are many arranged or fixed next to each other on a metal frame, the pump (*d*), the candle filter (*e*), the glass goose neck (*f*), the spinneret (*g*), and coagulating bath (*a*), are exactly the same as in bobbin type machine. The difference between the bobbin and centrifugal method lies inly in the fact that in the first case the thread is wound on a bobbin untwisted, and in the latter the thread, also made up of a number of filaments, is carried over a glass pulley, known as the Godet roller (*r*), to the centrifugal pot (*j*), after passing through the glass spinning funnel (*i*) which centers and distributes the thread in the pot which is revolved at high speed by motor (*k*), one of which is attached to each spinning pot.

These spinning machines, for either method, are made up of many spinning units arranged side by side on a lead protected iron frame. As many as 140 of the spinning units are placed on these frames, 70 on each side of the frame (see Figs. 75 and 76). Each unit has its own special spinning pump, a special candle filter, its own glass goose neck at the end of which is fixed the jet or spinneret which is made of a platinum alloy. Each spinneret has a number of small holes, 16 or more for 150 denier. These spinneret holes are often small enough to produce a one denier filament.

In the bobbin method each spinning unit has its own bob-

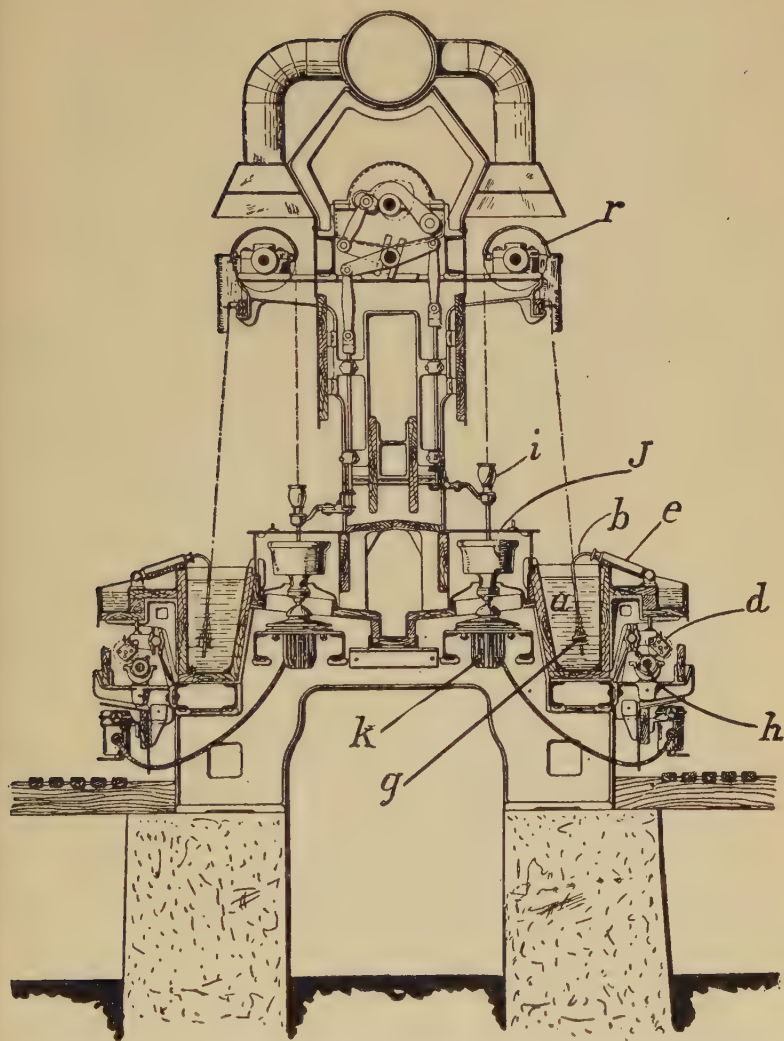


FIG. 76. Cross Section of Haubold Centrifugal Pot Spinning Machine,
(Courtesy C. G. Haubold, A. G., Chemnitz, Germany.)

bin to collect the threads. In the centrifugal method each unit has its own centrifugal pot to collect the thread upon its inner periphery. Only in the method of collecting the thread is there a difference in the spinning units.

The Bobbin Method.—The bobbin method, which was the first method used, is carried out by spinning machines of the type shown in Fig. 75. The function of these machines is to deliver, by means of the small individual pumps, a uniform quantity of solution, per unit of time, through the orifices in the spinneret, coagulate the solution in the spinning bath, and wind the resultant untwisted filaments upon a bobbin (*b*) (Fig. 75), to be later unwound for twisting on a separate special twisting machine. The Viscose solution is brought through pipe lines from the tanks, in which it has been stored during the final maturing period, to a distributing pipe running the length of the spinning machine. From this feed line manifold lateral branches lead to the spinning pumps. These pumps must deliver a constant and unvarying amount of solution through the spinnerets per unit of time. The spinning pumps are driven by gears mounted on a shaft (*h*) (Fig. 75) running lengthwise of the machine.

The spinning machine consists of a long metal frame carrying a double row of the spinning heads described in the previous sketches. (Figs. 75 and 76.). In Fig. 75 is given a cross-section of the bobbin spinning machine, clearly showing the assembled parts constituting the spinning head on each side of the metal frame; also the bobbin above, with the mechanism which regulates from a center mechanism on the frame, the spreading of the thread on the bobbin.

Inasmuch as the bobbin machine represents a composite mechanism upon the accuracy of operation of which depends the quality of the thread produced, it is essential to discuss the different devices and parts which combine in the spinning machine:

1. The pump, of which there are two types,
 - (a) The piston pump.
 - (b) The gear wheel pump.
2. The candle filter.
3. The glass goose neck.
4. The spinneret.
5. The bobbin.
6. The cross-winding mechanism spacing the thread on the bobbin.

1. *Spinning Pump.* The spinning pump plays an important part in the Viscose process. This pump must force an exact amount of solution through the spinneret per unit of time. This amount must remain constant regardless of varying pressures exerted against either the intake or discharge side of the pump. The difficulty of the problem is increased by the fact that the rate of delivery is small. A delivery of 10 cubic centimeters per minute is not uncommon for the Viscose spinning pump. Furthermore, the pump must stand up against a very corrosive solution which has a tendency to harden if allowed to stand for any length of time. It must be strong enough to withstand several atmospheres of pressure. And above all other things, it must deliver exactly the same amount of Viscose solution, per unit of time, as every other pump on the frame.

Clayton, an Englishman, developed the first really successful spinning pump. This was of the piston type, the gear type pumps being a more recent development. At the present time there is considerable competition between the two types for first place in the industry. In Germany the gear type appears to be in most general use, perhaps due to the higher cost of the piston type pumps.

(a) The Piston type pump was first patented by Stearn in 1903. It was a single piston pump with the necessary inlet and outlet valves. The Clayton piston pump however is the

best for the purpose, see Figs. 77 and 78. This pump is designed with two or four pistons. In the Figs. 72 and 73, the pistons (25 and 26) move back and forth in bores (20 and 21) of a revolving cylinder (7) within the casing (1). The back and forth movement of the pistons is against a stationary cam (41). The amount of pumping can be regulated by adjusting the stroke of the piston, by 5 to 10 per cent, by changing the angle of the cam (41). An air bottle (36) is attached to the pump in order to equalize the pressure between the strokes of the various pistons.

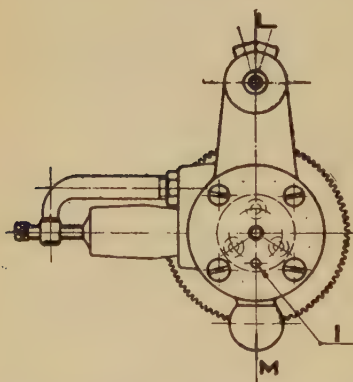


FIG. 77. Borletti Piston Pump, Showing Side View. (Courtesy Fratelli Borletti, Milan.)

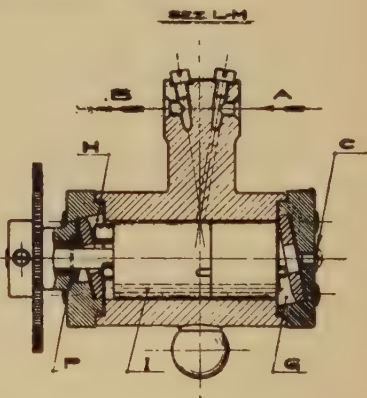


FIG. 78. Borletti Piston Pump, Longitudinal Section. (Courtesy Fratelli Borletti, Milan.)

Improvements in the piston type of pump still continue as the aim is absolute accuracy in the amount of Viscose solution delivered to the spinnerets. This is best attained with multiple-piston pumps, such as the Borletti pump (see Fig. 79), which operates with three pistons and two cams. The variation in the delivery of this pump is claimed to be less than 1 per cent. In order to attain still greater accuracy in delivery, the tendency is to build pumps with more than three pistons, and as many as nine pistons may be used in a single

pump. With such multiple-piston pumps, a much greater accuracy of delivery is obtainable and the variations in the delivery between different pumps may be less than 1 per cent. The piston pumps, as a class, are more complicated and expensive than those of the gear type, but at the same time have the advantage of greater accuracy.

As the air bottle of the pump is partially filled with Vis-

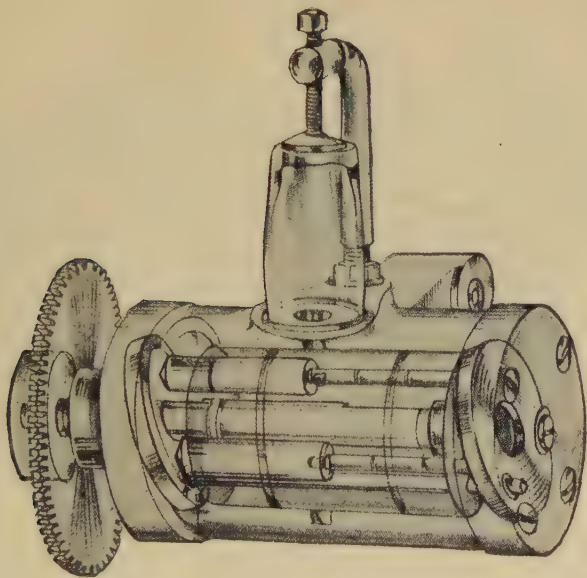


FIG. 79. Borletti Spinning Pump, showing Pistons and Air Bottle.
(Courtesy Fratelli Borletti, Milan.)

cose, this solution must be removed and renewed constantly, otherwise the surface of the solution will coagulate and harden, which may cause breakage of the pump or air chamber.

(b) In the gear wheel pump the Viscose solution is pumped by the rotation of two accurately cut intermeshing gears *b-b* (see Fig. 80). Adjustment is arranged for in the radial

position of the gears *b-b*, which effects any required change in the flow of the solution. By means of screws (*cc*) the inside plate (*aa*) is adjustable to the circumference of each gear. Aside from the many good features of this pump, such as simplicity, cheapness, ease of cleaning, positive drive, etc., its gear wheels soon become worn out and an uneven delivery results.

Pumps of the gear wheel type require constant attention

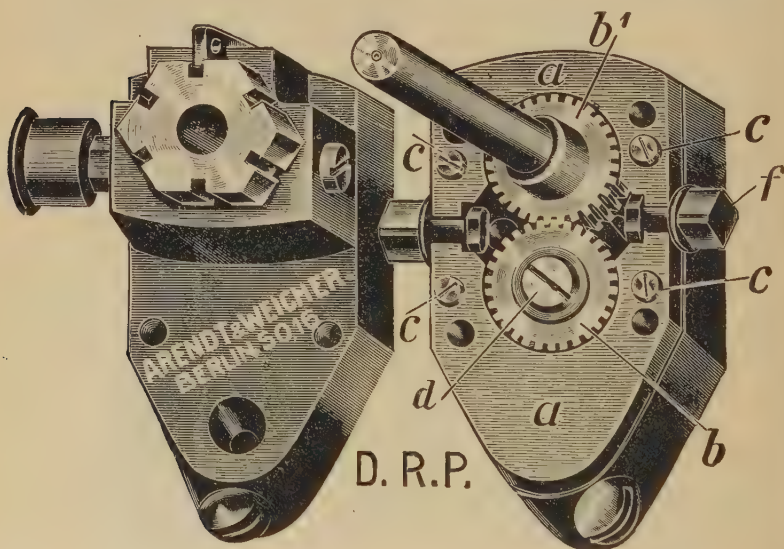


FIG. 80. Spinning Pump, Gear Type.

and must be tested from time to time, so that suitable adjustments of delivery can be made. Otherwise, the delivery may vary considerably more than the allowable plus or minus 2 per cent, thus causing considerable trouble and loss.

A number of pumps, of either type, are always kept in stock by the Rayon plants for quick replacement. These pumps weigh 6 or 7 pounds each.

2. *Candle Filter*.—From the pumps the solution is forced

through a candle-filter (Fig. 81) in which fine cambric removes any last traces of foreign matter that otherwise might clog the minute openings in the spinneret.

Figure 81 shows a construction of the candle filter which

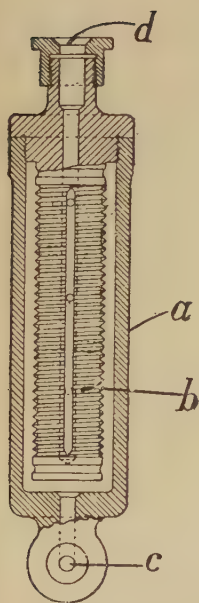


FIG. 81. Candle-Filter.

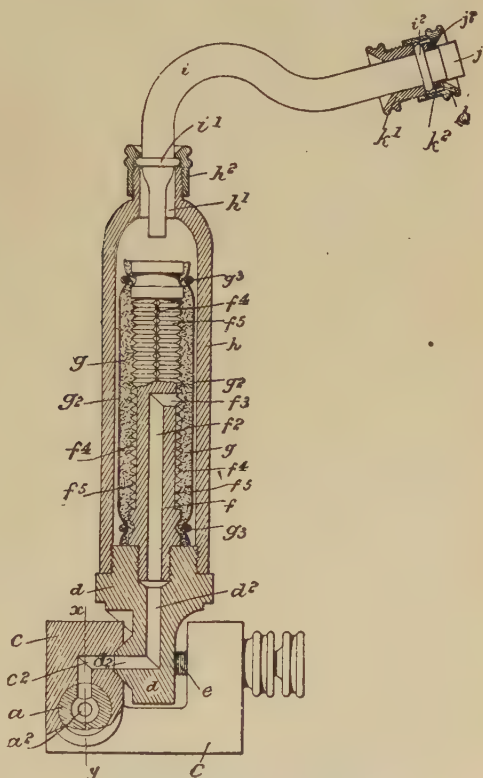


FIG. 82. Sectional Elevation of Bakelite Filter.
(Courtesy Wheeler.)

is composed of an outer hard rubber casing (a), and the inside serrated candle (b) of the same material. At the bottom is joint (c) to permit fixing and swivelling the filter onto a bracket. At (d) the glass goose neck, described later, is attached as shown assembled in Figure 82.

3. *The Glass Goose Neck* is that piece of glass tubing from the outlet end of the candle filter to the spinneret. Figure 82 shows how this tube (*i*) is attached to the candle filter (*h*) at the point (*i*) and also shows the spinneret (*j*) at the forward end of this glass tube. The shape of the bend is such as to make it possible to carry and hold the spinneret under the coagulating fluid (*a*) of the spinning machine.

4. *The Spinneret*, which is usually of a platinum alloy, is fastened to the goose neck with a lock-nut and is immersed directly in the neutralizing bath.

The spinneret, which was discussed in Chapter VIII on Fundamental Principles of Rayon Production, has a number of openings ranging in size from .003 inch to .0045 inch in diameter. The size of these openings, which are accurately drilled and evenly spaced, depends upon the concentration of the neutralizing bath, the nature of the spinning solution, the denier of Rayon to be spun, the speed of the take-up on the bobbin, and certain other factors. The number of the openings in each spinneret depends also on the same factors. The number of these openings controls the number of filaments in each thread. If the spinneret has eighteen openings, these eighteen filaments will comprise the finished thread when the subsequent steps in the process have been completed.

As shown in Fig. 83 the platinum alloy spinneret is made

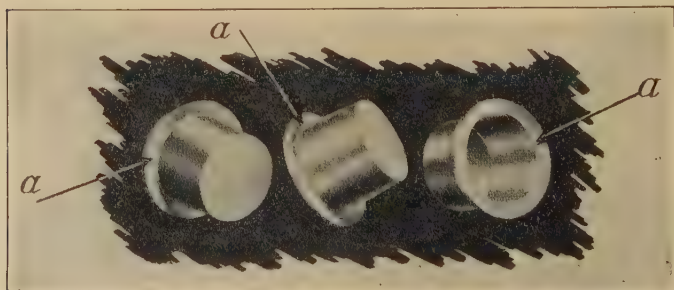


FIG. 83. Spinnerets—Metal Alloy. (Courtesy of Baker & Co., Inc.)

like a small cup with a flange (*a*) at the top, to make contact with the glass goose neck. The bottom of the cup is closed excepting for the little holes drilled in it to allow the solution to pass through and form the filaments. The size of these spinnerets is practically as shown in Fig. 83, or approximately 0.7 inch across the flange, 0.35 inch deep, and 0.5 inch in diameter on the closed end. The metal alloy spinnerets are made of platinum, gold-palladium and platinum-iridium. The glass spinneret is usually made by sealing wires in fine metal and chemically dissolving these wires out of the blown spinneret. The 150 denier hole, allowing 18 to 24 holes in each spinneret to produce this denier, is either 0.004 of an inch in size or as low as 0.002 of an inch.

Until recently, the ordinary 150 denier yarn consisted of only 16, 18, or 25 filaments, varying in size from about 9.4 to 6 deniers each. The tendency towards a better product, more nearly resembling true silk in many properties, has resulted in finer filaments so that more of them are necessary to make the 150 denier thread. The holes are being drilled much finer, for example, as low as 2 deniers for each filament, giving as many as 75 holes in a spinneret for a commercial 150 denier Viscose yarn.

(Note: Viscose filaments of much lower denier have also been produced upon a small scale but are not yet commercially available in America. However, finer filaments, such as 0.625 denier, are now produced commercially by other processes.)

The manufacture of the spinneret is a highly technical problem as the accuracy of the holes must be close and the variation between the size of one hole as compared to another should be infinitesimal, less than .0001 of an inch. To insure such accuracy, extremely precise measuring apparatus has recently been developed for the measurement of the spinneret holes. This process of measurement magnifies the hole 150

times or more and throws the picture of the magnified hole upon a ground plate glass where any lack of uniformity of the hole is quickly noted and the spinnerets corrected or eliminated.

5. *The Bobbin*.—As the solution emerges from the spinneret into the neutralizing bath, the chemical action of the bath hardens each tiny stream of liquid into a filament, and these filaments are drawn up out of the bath and wound on the bobbin. The bobbins are rotated at the correct rate of speed to synchronize with the speed of delivery of the Viscose through the spinneret. The driving mechanism furnishing power for the bobbins is located at the end of the spinning frame. One of the very important features of this mechanism is an arrangement for compensating for the increased diameter of the bobbin during the spinning period. The external diameter of the spool constantly increases as the Rayon is wound on, and this mechanism must automatically and accurately decrease the number of revolutions of the bobbin, so that the same surface speed will be maintained from the beginning to the end of the spinning period of the bobbin. Unless this is done uneven Rayon will result.

6. *Cross-winding Mechanism*.—A moving arm or guide travels back and forth across the bobbin face guiding the Rayon on the bobbin. Care must be taken that this cross-winding is such that no trouble will be encountered when the bobbin is later unwound in the spooling or the twisting operation. A porcelain tray under the bobbin catches the drip of the spinning bath left in the Rayon. Spinning machines have as many as one hundred and forty spinning units to each frame, seventy to a side. The average length of one of these machines is about seventy feet. Since the sulphuric acid used in the spinning bath is highly active, every precaution must be taken to prevent corrosion either from direct contact or

from the effect of the fumes. The spinning bath troughs are lead-lined, the Rayon guides are either glass or porcelain, gears and other moving parts must be protected, and the parts that are immersed directly in the spinning bath are made either of glass, hard rubber or some other substances that will resist the acid.

The bobbins used are sometimes of glass. While this is excellent to withstand corrosion, the glass bobbins are clumsy and awkward to handle, and the breakage runs high. Other bobbins are made of aluminum and covered with a protective coating of acid resistant lacquer. Paper bobbins, similarly covered, have been tried in Europe but with what success is not known at the present time.

Bobbin spinning machines are now designed to include automatic mechanisms which will change over from a full to an empty bobbin without stopping the spinning operation. The usual speed of bobbin spinning is about 140 feet per minute.

The above principal devices compose, after leaving out of consideration many stationary details, the bobbin spinning machine. The spinning machine as at present built represents quite an advance over the early machines. This advance is due to the cooperation between the chemical engineer on the one hand and the mechanical engineer on the other. The various movements in the machine must be accurately timed and coordinated, and the machine must be sturdy and strong. Undoubtedly the present machine does not represent the ultimate in achievement and continued cooperation will no doubt result in still further improvements.

The Pot Method of Spinning.—The early demand for Rayon yarn called for a faster spinning machine than was possible by the bobbin process then in use. These requirements were met by the centrifugal pot spinning machine. The disadvantages at first encountered in this spinning method

have largely been eliminated. This refers particularly to the difficulties formerly experienced with the various driving mechanisms for the spinning pots.

In Fig. 82 a modern centrifugal pot spinning machine is shown. The spinning solution is forced by air pressure from storage tanks to a distributor pipe, from which branches lead to the spinning pumps. The spinning pumps force the solution through the candle filters, through the goose neck, and out through the spinneret into the spinning bath. Up to this point the method and equipment are virtually the same as those used in the bobbin spinning method. From this point on, however, there is quite a difference in the two methods.

The Godet Wheel or Roller.—

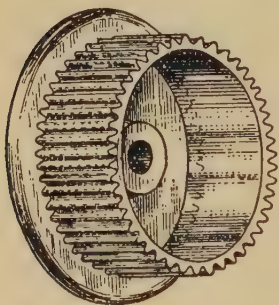


FIG. 84. Godet Roller.

As the filaments come up out of the precipitating bath, passing through and adjustable round glass hook which determines the immersion of the filaments, they are carried almost vertically up to a roller or feed wheel known as the Godet wheel (see Fig. 84). The filaments are carried around this roller and then drop straight down into the revolving centrifugal pot. The spinning speed or the rate at which the thread is produced at the spinneret is largely determined by the peripheral speed of the Godet wheel. As already explained, there is some slip over this wheel which is due to the pull exerted on the thread by the centrifugal pot. This wheel is made of glass or hard rubber with a serrated or plain surface.

The Funnel.—The filaments passed through a glass funnel on the passage into this pot, and this funnel, by moving up and down, controls the pile-up of the thread within the pot (see Fig. 85). This funnel is made of glass and arranged

so as to permit adjustment of its collar for centering the thread.

The Centrifugal Spinning Pot.—The spinning pot revolves from 5000 to 6000 times per minute. Between the point where the filaments leave the wheel and where they are piled up in the pot, the filaments are twisted to form the thread.

The amount of twist imparted depends upon the speed of the delivery of the thread and the number of revolutions per minute of the pot. In order to determine the twist we may refer to Fig. 76. At the spinneret (*g*) the filaments are coagulated and carried over the glass revolving wheel (*r*), known as the Godet wheel. At (*r*) the thread drops down vertically into glass funnel (*i*) which the thread leaves at right angles to coil, while twisting, in the rapidly revolving pot (*j*) to form a "cake." The twist or turns per inch of thread is computed by dividing the revolutions of the pot (in R.P.M.) by the spinning speed, in inches per minute. Thus if revolutions of the pot are 6000 per minute and spinning speed is 2000 inches per minute, the twist obtained per inch of thread produced will be:

$$\frac{6000 \text{ R.P.M.}}{2000 \text{ inches}} = 3 \text{ turns}$$

This is a theoretical calculation, taken as an example to indicate the method of computation. The actual result must take into consideration the correction necessary to make up the slip of the thread in going over the Godet wheel. The usual twist is about $2\frac{1}{2}$ turns per inch. As the pot revolves the thread is spirally wound around the inside of the pot in what is known as a cake. When the required amount of thread has been piled inside the pot, the pot is lifted off the



FIG. 85.
Spinning
Funnel.

spindle and the cake is transferred to a board. The driving of the pots must be positive and as they run at a high rate of speed, they must be perfectly balanced. Absence of this balance would result in excessive vibration. The pots must be easily removable and they must also be interchangeable. Small holes are drilled all around the periphery of the pot to permit the excess liquid in the thread to escape, due to the centrifugal force exerted by the rotation of the pot. The pot is usually of aluminum with an acid resisting lining. Many types of pots have been tried. The corrosive action of the sulphuric acid present makes necessary some material resistant to the corrosive action of this acid. An all-rubber pot has been developed to meet the rather severe requirements of pot spinning. Bakelite pots are being used successfully and large numbers are manufactured by the Bakelite Corporation.

The individually electric-driven spinning pot is a recent development. In Fig. 86 one of these is known. It has, without question, many advantages. It simplifies the drive since many moving parts are eliminated. Each spinning pot can be stopped or started without regard for the other pots on the same machine. In this type of pot the motor plays an all important part and those now on the market are highly specialized and were particularly developed for this work. The Westinghouse Electric and Manufacturing Company have developed a motor for this purpose. The particular features of the motor are as follows:

Ball bearings of large capacity are used to amply withstand the end and also the radial thrust. They are lubricated with oil from an oil-well below, the oil being pumped up over the balls by the action of the revolving shaft-parts submerged in the oil. Immediately above the top-bearing housing of the motor is a liquid thrower which prevents any liquid from passing down the shaft into the motor. This thrower is a press fit on the shaft so that no liquid can get down between it and the shaft. In addition, at the top of

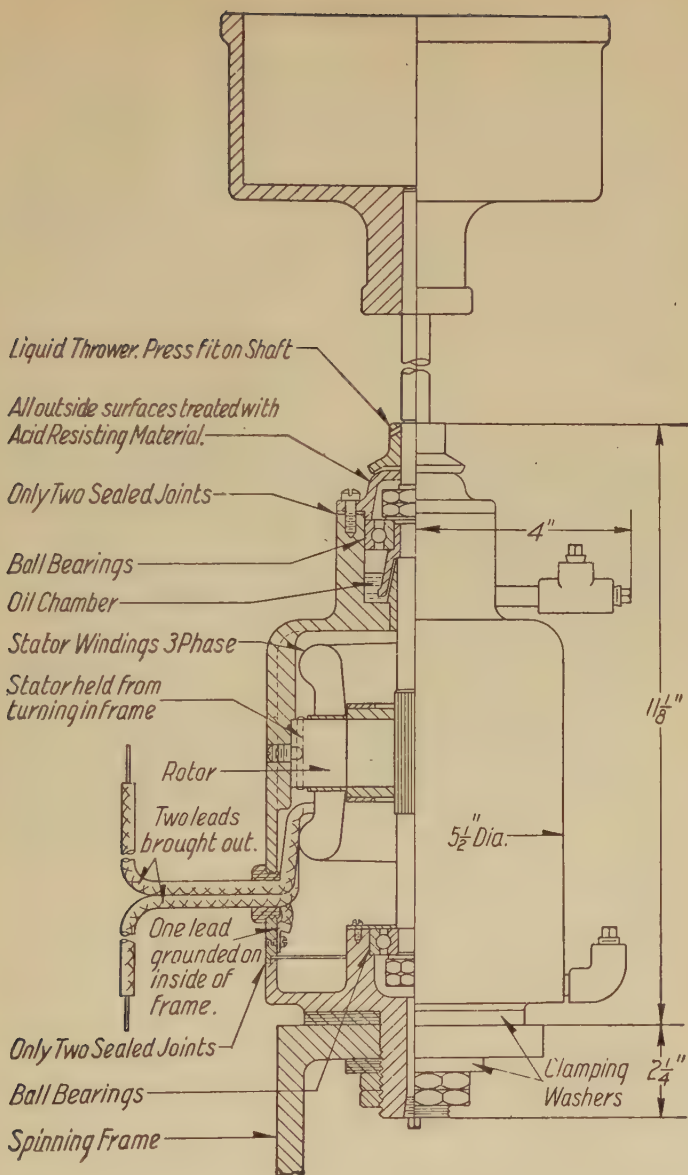


FIG. 86. Spinning Pot or Box, Motor Driven (Courtesy of Westinghouse Company.)

this is an annular ring with a discharge opening that permits any of the liquor resting on the top of this thrower to fall on this ring and be thrown out through the opening. Any liquor falling on the surface of the thrower is thrown off by centrifugal force into the receiving chamber. The motor has the upper and lower bracket completely sealed against moisture and the whole motor surface is completely covered with an acid- and moisture-resisting baked varnish, thus protecting the entire motor from moisture and acid.

Aside from the general mechanical and electrical parts which make the balance of the spinning machine, the above are the principal elements in the pot spinning machine which are directly responsible for the production of the Rayon thread.

The pot-type spinning machine represents, just as the bobbin type does, the result of close cooperation between the chemical and mechanical engineers. It must have most of the elements found in the bobbin-type machine with the driving of the pots as an added problem.

It is evident that centrifugal spinning is more economical than the bobbin spinning method, especially as the spinning and twisting are combined in one operation on the centrifugal spinning machine. Besides, the cakes removed from the spinning pots are immediately placed on the reeling machines to be made up into skeins, which results in a very much simplified washing process and a great saving of water.

Further, by this method the twisted filaments are deposited on the inner side of the pot by centrifugal force without any strain, which is not the case in the bobbin method, where the thread dries and contracts on the solid bobbin.

In addition to this, the pot holds a considerably larger amount of thread than the bobbin, about one pound being the usual weight of the Rayon cake. When the desired weight of Rayon is in the pot, the attendant stops the filaments, puts the break on the pot to stop it, and replaces the full pot with an empty one, all in less than one minute. As an outline, the

cakes are then reeled into skeins of the desired weight, or length, which are tied with colored tie-bands to indicate the denier of the thread.

One further important factor is the smaller floor space required for a plant to produce Rayon by the centrifugal spinning system. While the bobbin method produces the finer yarns (below 100 deniers) the centrifugal pot method is more universally used. The steady and rapid improvements in the pot spinning machine make it highly probable that it may soon be possible to produce the finer yarns by this method also.

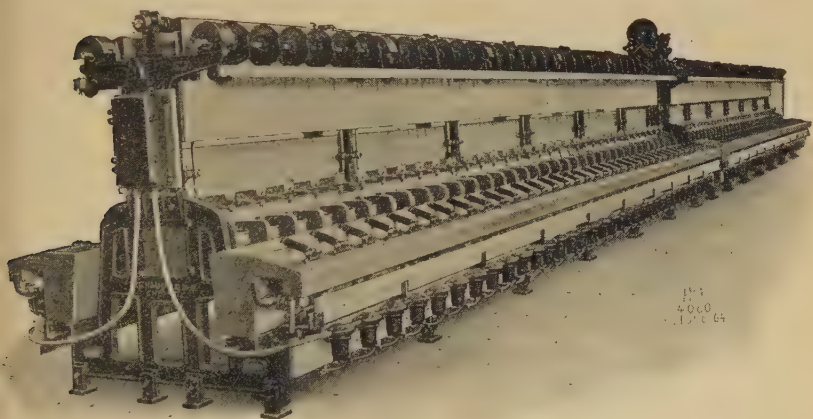


FIG. 87. Centrifugal Viscose Rayon Spinning Machine. (Courtesy of C. G. Haubold A. G., Chemnitz, Germany.)

One of the double-sided centrifugal spinning machines, *i.e.*, with spinning sets on both sides, as is usually the case, is shown in Fig. 87. In this type of machine, the number of spinning sets depends upon the output required. The machine shown is supplied with individual motor drive on the spinning pots—which is now generally preferred—or with mechanical or hydraulic drive. These spinning boxes consist of either aluminum with acid-resisting ebonite lining or of bakelite.

The spinning boxes are of a slightly conical shape and perforated on their sides so that the liquid from the spinning bath may escape by centrifugal force. As a rule, each box is driven from a separate small motor. These motors generally run at a speed of up to 6000 revolutions per minute. They reach full speed very quickly so that the spinning boxes start their rotary motion without any jerks and are soon balanced. In this way, a uniform thread from beginning to end is formed into a cake.

All driving parts are suitably protected against damage from the acid. Special cast iron lead-coated hoods are placed above the spinning motors to protect them from acid. Also the parts forming the casting for the spinning boxes are made of acid-resisting material. These casings are covered by lids similarly protected and arranged to be easily removed. The partitions and covers for the spinning bath chamber or trough are of extra large size and are made of compressed bakelite inserted in frames of lead. Provision has been made to draw off all noxious fumes formed inside the machine, which are liable to affect the health of the workmen, a matter which will be more fully described later.

The other moving parts of the machine (funnels, glass rolls, drive of spinning pumps) are actuated by separate motors with a joint starter. This permits dispensing with many of the gears and shafts otherwise required, rendering the maintenance easier. One important advantage of this type of spinning machine is that no parts requiring any attendance are placed below the frames where it would be very inconvenient to reach them. Even the small driving motors for the spinning boxes can be easily unfastened and lifted out from the top. The lubrication for the ball bearings of these motors will last for many months. The Rayon thread on its way from the glass Godet wheel to the spinning box receives an even twist. The number of revolutions of the spinning

box can be varied by altering the frequency of the electric current. For each motor an electric brake switch is provided which stops the rotation almost instantaneously, to quickly remove the full box with the cake. The interruptions in the manufacturing process are thus reduced to a minimum. The Viscose for each spinning set is supplied by either a gear or piston pump of approved design to fit exactly any denier of thread required.

During the spinning operation for both the bobbin and pot method, considerable quantities of fumes are created. These fumes are most unpleasant and must be removed promptly and fresh air supplied to take the place of the foul air removed. Hoods are usually placed over the spinning machines for this purpose and suction fans pull out the spent air, exhausting into ducts that lead to fume-towers where the noxious gases are neutralized, as tall chimneys will not prevent a poisonous atmosphere. Fresh air is supplied by means of fans to take the place of the foul air removed.

One of the methods of decomposing these poisonous gases in the atmosphere is to pass the exhaust air from the spinning machines through a grid ozonizer (see Fig. 88).

In this apparatus the ozone, generated by the high voltage

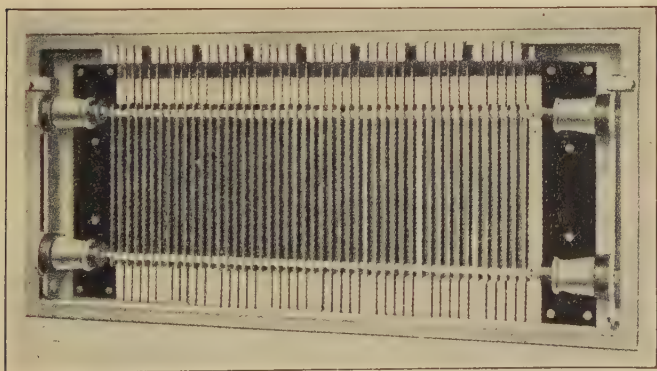


FIG. 88. Grid Ozonizer for Electric Air Purification.

electrical discharge in the ozonizer, oxidizes the obnoxious gases to compounds soluble in water, and these are removed by passing the exhaust gases through a scrubbing tower, such as that shown in Fig. 89. If some such method of purification is not adapted, this fume laden air, containing considerable poisonous hydrogen sulphite, may become a source of danger to the population living near the plant.

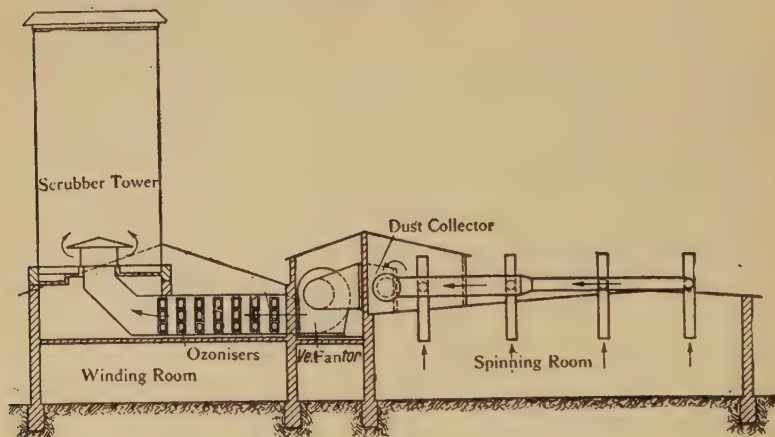


FIG. 89. Electric Air Purifying Apparatus on the Roof of an Artificial Silk Factory.

III. THE FINISHING OR PREPARATION OF YARN FOR THE USER

The finishing or preparation of yarn by the bobbin method.
 —The second stage of the Viscose process completes its cycle by finishing with a bobbin of thread, when using the bobbin spinning machine; or a cake of spun thread, when using the centrifugal pot spinning machine. Both the bobbin and the cake are wet with diluted acid and the third stage, therefore, starts with the treatment of the bobbin and cake so as to remove this acid and the excess of moisture.

If the Rayon plant is equipped with bobbin machines, we will continue the third stage, that is, the finishing, by considering the treatment of the bobbin from the spinning machine to the end of the process, the routing and time of each operation of which is as follows:

TABLE 87.—OPERATION CYCLE UNDER BOBBIN SPINNING METHOD

Routing Steps	Operation	Time in Hours
1.	Bobbin spinning machine.....	24
2.	Bobbin with thread.....	
3.	Washing of bobbins to eliminate acids.....	6
4.	Stretching and drying or storing...	3 to 4
5.	Twisting and spooling.....	40
6.	Reeling and lacing.....	4
7.	<div data-kind="parent" data-rs="5"> { Conducted in a continuous machine } </div> <div data-kind="parent" data-rs="5"> a. Desulphurizing..... b. Washing..... c. Bleaching..... d. Souring..... e. Washing..... </div>	2
8.	Hydro extracting.....	$\frac{1}{2}$
9.	Drying and humidifying.....	2 to 3
10.	Sorting and grading.....	$\frac{1}{2}$
11.	Knotting and packing.....	5 minutes
		82 to 84 hrs. 5 mins.

The above cycle of operations, Table 87, is based on the production of 2.25 pounds of 150 denier thread per 24 hours. It is noted that to twist 2.25 pounds continuously will take 40 hours, the time being far in excess of any of the other operations. In other words, twisting the dried filaments from the bobbin is a longer process than spinning the Viscose solution into filaments, which takes 24 hours. It will therefore take a larger number of twisting machines in order to reduce the time to that of the next longest operation, which is that

of spinning. It is the practice to place in operation a sufficiently large number of twisting machines to reduce this time to 16 hours so as to keep the female labor used on this operation on two shifts only.

According to the cycle, the first operation after spinning is that of:

Washing.—Following the spinning operation the bobbins filled with Rayon are passed through a washing operation to free the threads from acid. This is a rather troublesome operation. The Rayon, still in a semi-gelatinous state and quite thick on the bobbins, resists the removal of the acid. An early washing method was to place the bobbins on racks, each tier of bobbins being five or six high. Water was dripped over the top row of bobbins on to the next row and so on down to the lowest row. This method was slow, uncertain and troublesome, ties up a large number of bobbins, requires a large floor space, consumes a large quantity of water, and naturally slows down the cycle of operations. Many attempts have been made to improve on this method. In one improvement large tanks of water are used into which the bobbins are lowered on trucks while a slow current of water is constantly circulated through this tank. The most successful method now in use employs smaller perforated bobbins. These bobbins are placed end to end forming a tube (see Fig. 90). The line is immersed in water and the water is pulled through the bobbins by suction.

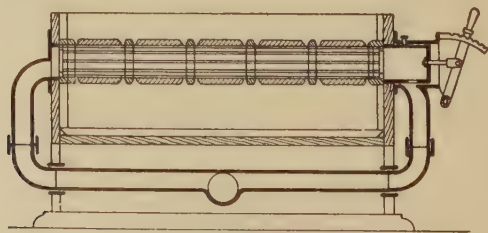


FIG. 90. Bobbin Washing Machine (Kohorn).

This method results in cutting down the washing time from a matter of days to hours. It is also claimed that the quality of the Rayon is improved and that unwinding is made easier. In the United States we find an application of this principle in a rotary type of washing machine recently developed. This machine consists of a circular plate or drum holding about 50 bobbins. The bobbins, as they come from the spinning machine, are placed in position on the plate, locked fast and the plate immersed in a lead-lined tank. Then the water in the tank is sucked through the layers of Rayon by means of vacuum. All of the advantages claimed for the line-vacuum type of washer are also claimed for the rotary type.

Stretching and Drying or Storing.—After the washing operation the Rayon is dried and stretched. The bobbins are transferred from the washing machines to truck frames which are wheeled into a drying chamber or tunnel. In general this drier follows quite closely the lines of driers used for other textile fibres, etc.

In Figs. 91 and 92 bobbin driers of a type quite often used are shown. It is a heat-insulated chamber equipped with gilled steam pipes, humidity-sprays and disc fans for circulation of the heated air.

Humidity and temperature control devices are also provided. The temperature maintained in the chamber ranges in different plants from 104 to 140 degrees Fahr. During the drying operation the Rayon shrinks somewhat on the bobbins.

After the Rayon has been brought down to a low moisture content it is cooled and then a certain amount of moisture, not to exceed 10 per cent, is put back in order to make the subsequent operations of spooling and twisting easier. This cooling and regain of moisture can be conducted in the same chamber in which the drying is done, but it is preferable to do it in a separate room.

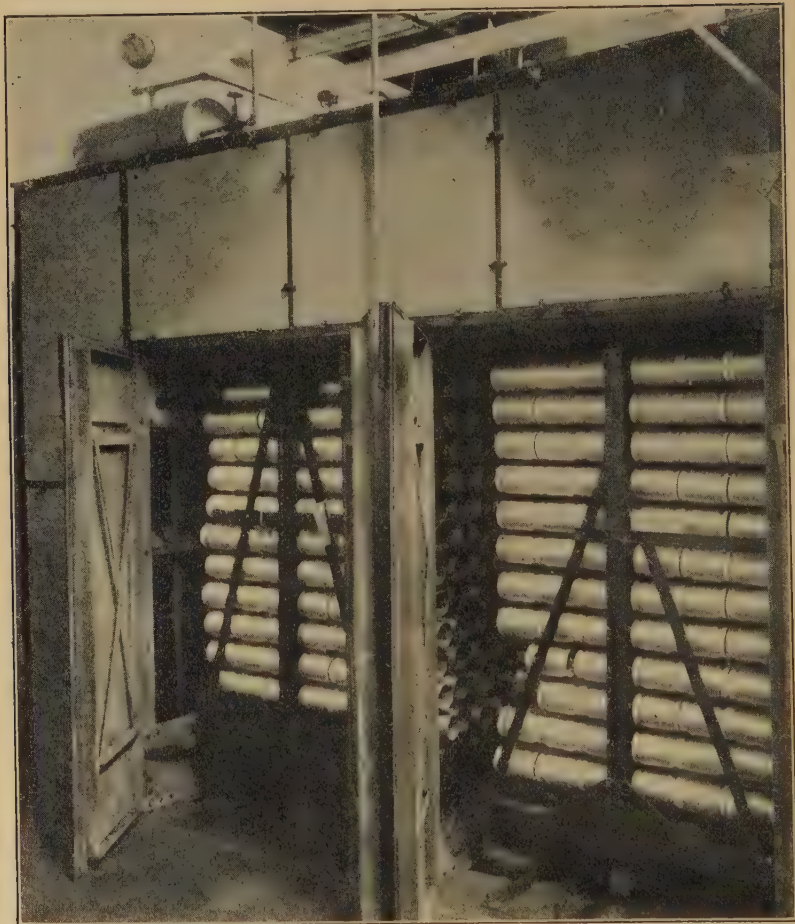


FIG. 91. Bobbin Dryer.

Twisting and Spooling.—The filaments wound on the bobbin lie parallel to each other and these must now be twisted together to form them into one thread. Sometimes the Rayon is first rewound from these spinning bobbins to smaller ones known as spools. This operation is called spooling. Spooling is done to permit easier handling and to speed up the twisting operation.

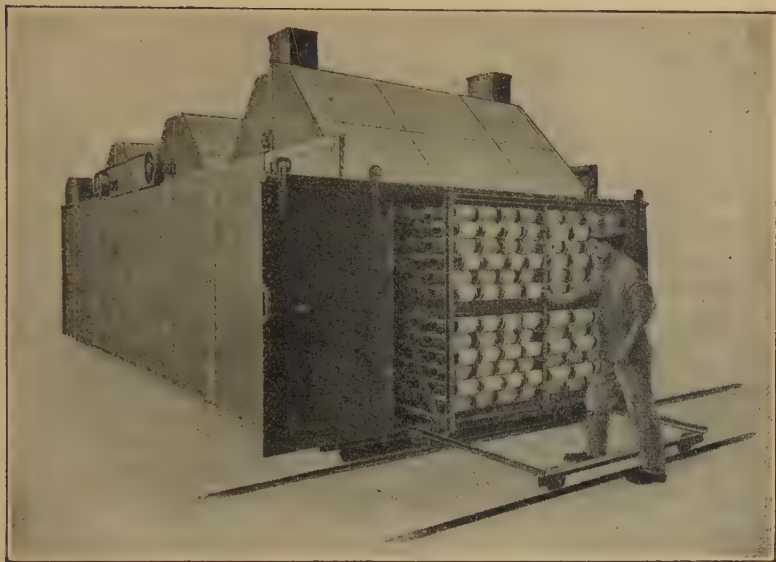


FIG. 92. Drying of Yarns on Bobbins. (Haas-Lenep.)

From the spooling machine the Rayon goes to the twisters. On the twisting machine the Rayon is unwound from the spool and carried down to a spool which revolves rapidly on a spindle, thus receiving the desired twist. The latest development are the machines which twist direct from the spinning bobbin without re-spooling. This is quite an economy. A machine of this type is shown in Fig. 93 which is a two-decker, double-sided, twisting machine.

As noted from Fig. 93 the bobbins are placed vertically on the spindles of the twisting machine, which revolve at a very high rate of speed. During this operation the thread is unwound and passes onto a horizontal spool rotating at a slower speed. The twist is caused by the ballooning of the thread due to the high speed of the lower spool. The desired twist is obtained by adjusting the peripheral speed of the horizontal spool and the speed of lower vertical bobbin.

Reeling and Lacing.—The twisted Rayon, now on spools,

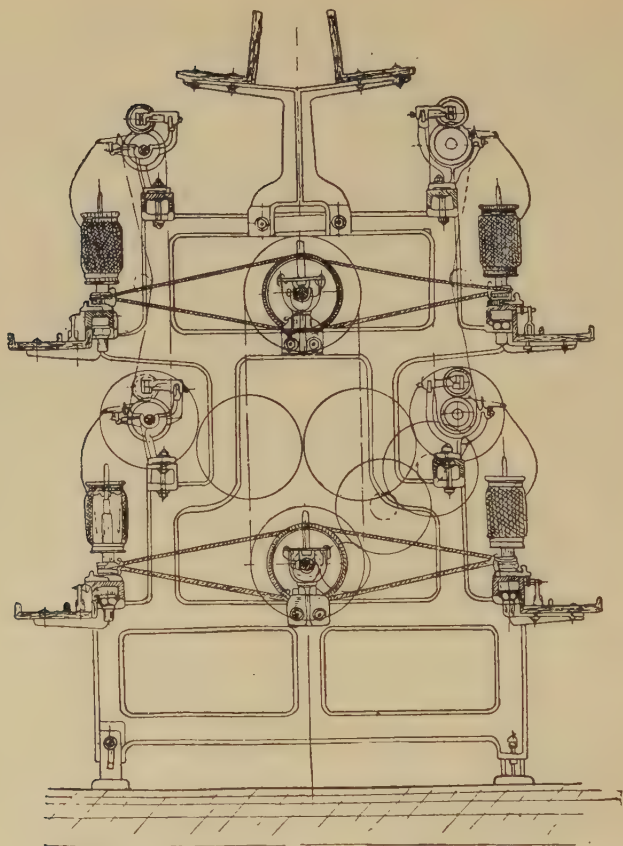


FIG. 93. Two-decker Twisting Machine. (Courtesy Wheeler.)

is taken to the reeling room where it is skeined. The spools are placed on the holding device or reel, the thread passed through porcelain guides and onto the reel-fly or swift. A rail moving back and forth regulates the cross winding. Each fly is fitted with an automatic stop so that when the threads break, the reel stops. There is also a device to stop the reel when the required number of yards has been wound on the fly.

The standard-size skein of Rayon is 44 inches. The

number of yards per skein varies with the denier of the Rayon and the trade requirements of the individual producer. After the required amount of Rayon has been wound into the skein, it is laced through with tiebands which are inserted and tied. To do this the reel-fly is taken out of the reel and placed in a holding stand. The fly is then partly collapsed, and the skeins are slipped off and hung on poles. Figures 99, 100, 101 and 102, showing the reeling machine and the skein handling devices, are the same for spun cake as for bobbin reeling.

FINAL TREATMENT OF REELED SKEINS

Desulphurizing.—The Rayon, now in the form of skeins, still contains the combined sulphur present in the ripened Viscose spinning solution and it is necessary to remove this before bleaching and finishing the Rayon. This sulphur is removed by means of a desulphurizing process, usually consisting of a treatment at 104 to 122 degrees Fahr. with a 0.75 to 1 per cent aqueous sodium sulphide solution for 15 to 60 minutes. Sodium phosphate solution has also been used for this purpose. The sulphur present in the Viscose is soluble in the sulphide solution, with the formation of sodium polysulphides. As these higher sulphides have much less solvent action upon the sulphur, it is necessary to either continuously renew the sulphide solution or to regenerate the sodium sulphide (Na_2S) by the addition of caustic soda and an organic reducing agent, such as glucose.

Washing.—Immediately following the desulphurizing operation, washing of the skeins in clean water takes place (see Fig. 94), from which point the skein follows in continuous sequence to the next step of bleaching, provided this is desired.

Bleaching.—When the skeins are to be bleached, this operation follows the washing, using practically the same type of

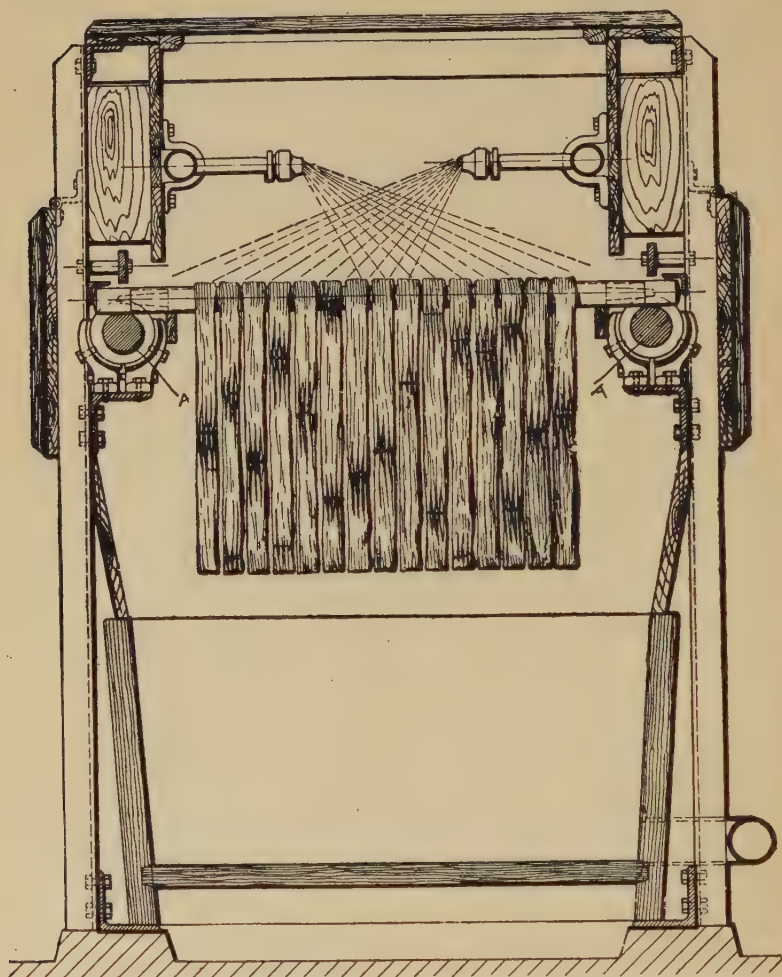


FIG. 94. Front View—Skein Washing, Desulphurising, Bleaching, Souring Machine. (Courtesy C. G. Haubold A. G., Chemnitz.)

machine (Figs. 94 and 95), with either a solution of sodium or calcium hypochlorite (bleaching powder), containing 0.5 to 1 per cent of available chlorine.

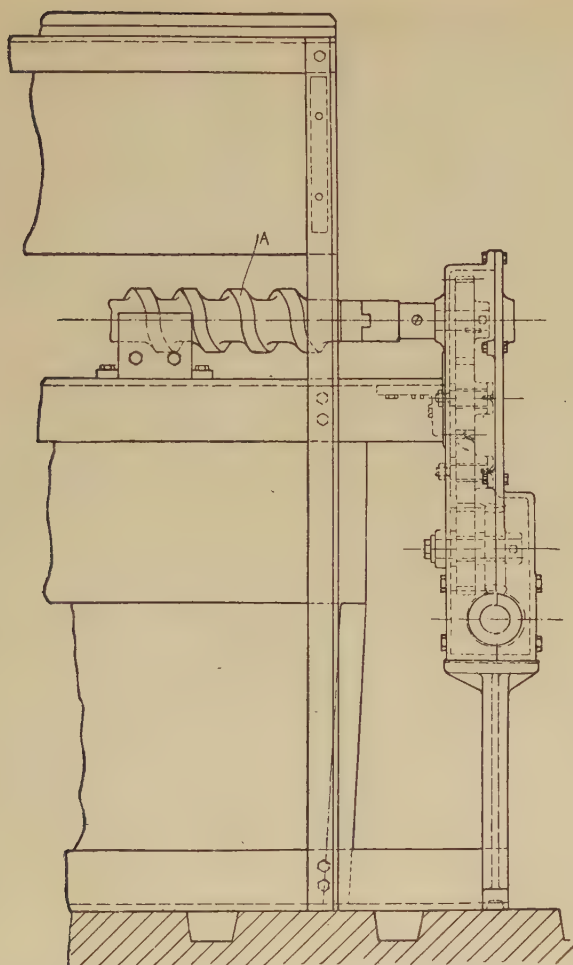


FIG. 95. Side View Part of Washing Machine, Fig. 94. (Courtesy of C. G. Haubold A. G., Chemnitz.)

Souring.—The bleached or unbleached skeins are next treated with a 0.5 per cent solution of hydrochloric acid and finally washed well with fresh water until free from all traces of free chlorine and acid.

All of the above operations, from the beginning of the de-sulphurizing treatment to the final washing, can be and frequently are carried out in a continuous type of washing machine, such as that shown in Figs. 94 and 95. On this type of machine the skeins are supported by glass or bakelite or similar rods or rollers, and these are carried forward by two screw conveyors *A-A*, one at each side of the machine. As the skeins proceed through the long machine, they are sprayed at every point (due to the revolving of the rods as they go forward) with the sulphide solution, rinse water, bleaching solution, acid solution, and final wash water, leaving the skein in a wet but sulphur-free and bleached state.

Centrifuge Hydro-extracting.—The washed skeins are usually packed in cloth bags and centrifuged to remove as much water as possible before the actual drying operation. Figure 96 shows a centrifuge hydro-extractor of the type commonly used for this purpose but numerous American centrifuges are also available. The idea in placing the skeins in bags or wrapping them in cloths before centrifuging is to protect the delicate wet filaments of the yarn and to prevent, as much as possible, any movement of the various threads in the skeins, which latter might cause serious trouble in rewinding. It is also necessary to carefully pack the wrapped skeins in the bowl of the centrifuge, so as to prevent any shifting of the load and to obtain uniform results, without injury to the extractor.

Drying and Humidifying.—The skeins are now placed on poles or sticks, which are either supported by wheeled frames (trucks) or by the endless chains of a continuous dryer, such as is shown in Fig. 97. These trucks are then wheeled into a drying chamber. In either case the skeins are exposed for some time to a current of dry air traveling at the rate of about 10 feet per second and at a temperature of 85 to 120 degrees Fahr. The speed of this current of air is just sufficient to



FIG. 96. Hydro-extractor.

move the Rayon threads slightly, which not only facilitates drying but is claimed to increase the covering power of the finished product. The usual practice is to either only dry the skeins to the point where they contain about 11 per cent of moisture, or to carry the drying beyond this point and then recondition them to 1 per cent of moisture.

Sorting and Grading.—No step in the process of making

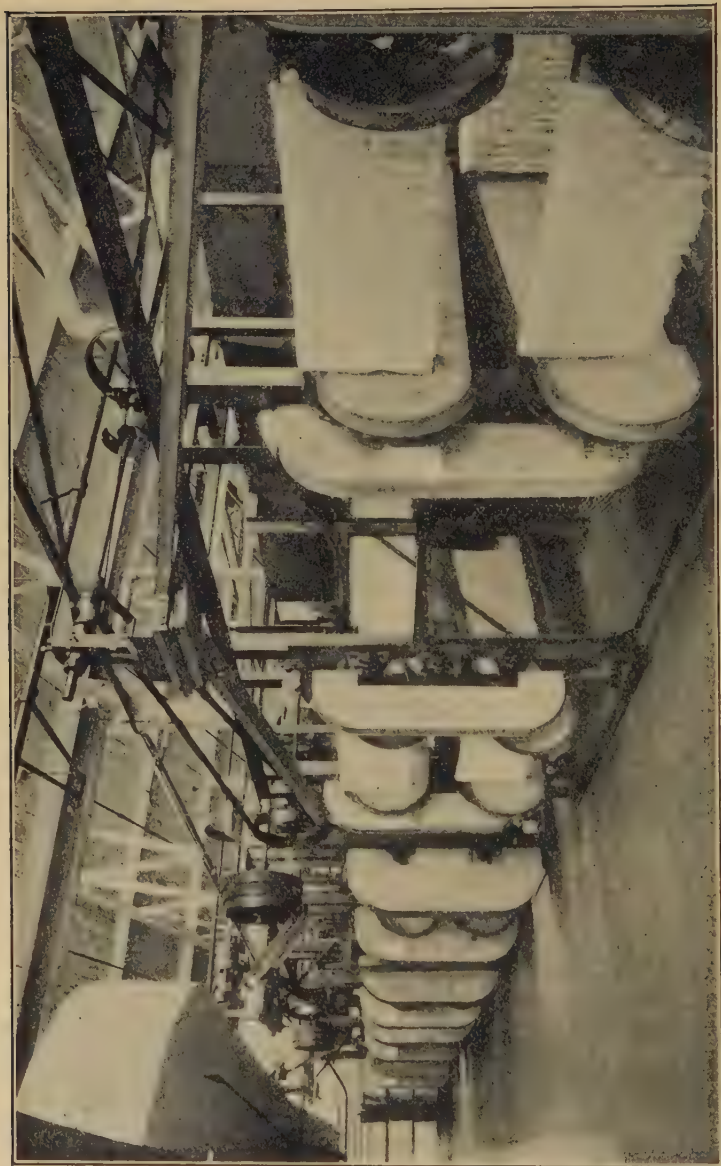


FIG. 97. Automatic Final Skein Drying and Conditioning Chamber Operating at the Industrial Rayon Corporation. (Proctor and Schwartz, Philadelphia, Builders.)

Rayon is of greater importance than the sorting and grading. The problem involved in this step is not one of chemistry or of equipment, but one of management and personnel training. The ideal of all plants is to produce 100 per cent perfect Rayon. This is, of course, impossible of realization. Therefore careful sorting and grading is necessary. Two grades are now marketed, known as "first" and "second" grades. Sometimes a third grade known as "Inferior" finds its way into the market. The operators sort and classify the skeins into these grades. In order to sort the skeins in correct deniers the weight of each skein is also checked.

Girls are employed for this operation and they are specially trained for the work. Their hands must be free from rough places and their eyes and their sense of touch must be keen. A careful system of resorting is maintained in order to make sure that the sorting is up to standard.

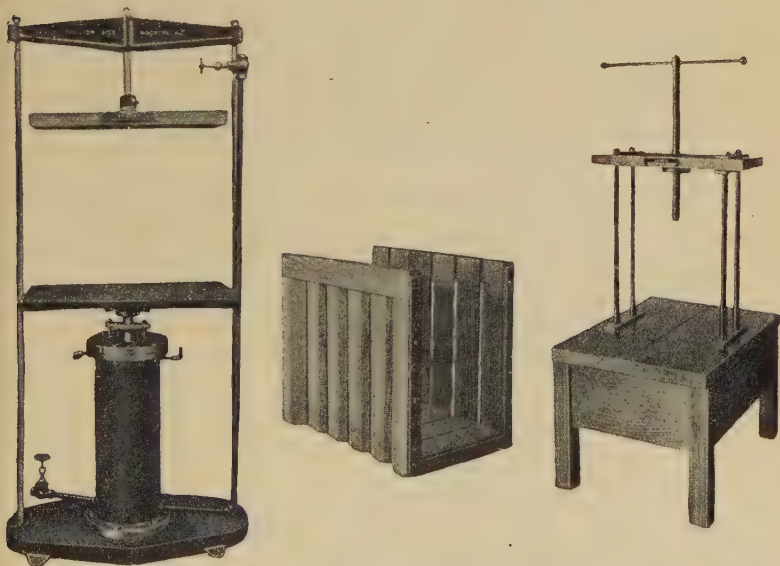


FIG. 98. Power Press, Bundling Box and Hand Press for Bundling and Packing the Rayon Skeins.

Bundling and Packing.—Following the sorting operation the skeins are bundled and packed. Bundles, usually of ten or eleven pounds, are packed in cases containing twenty, twenty-two or twenty-four bundles. Bundling is done by means of boxes and presses of the types shown in Fig. 98.

Finishing of Yarn Produced by the Centrifugal Pot Method.—The finishing operations upon yarn in the form of “cakes” is somewhat simpler than that produced by the bobbin method, the finishing process of which has just been described, in that the thread in the cake already has a twist of about $2\frac{1}{2}$ turns per inch, therefore, no twisting and spooling of the yarn is necessary. This results not only in a saving in plant space and investment, but also in considerable saving in labor costs, as well as in handling, which is very desirable. The cycle of operations used in finishing pot-spun yarn is given below.

TABLE 88.—OPERATION CYCLE UNDER CENTRIFUGAL-POT METHOD

Routing Steps	Operation Cycle	Time in Hours
1.	Centrifugal spinning machine.	24
2.	“Cakes”	
3.	Steaming or humidifying in special chamber.	2
4.	Reeling and lacing.	8
5.	Washing to eliminate acid.	$\frac{1}{2}$
6.	Drying under tension.	3 to 4
7.	Conducted in a continuous machine a. Desulphurizing. b. Washing. c. Bleaching. d. Souring. e. Washing.	2
8.	Hydro-extracting.	$\frac{1}{2}$
9.	Drying and humidifying.	2 to 3
10.	Sorting and grading.	$\frac{1}{2}$
11.	Knotting and packing.	5 minutes
	Total time of finishing.	42 to 44 hrs. 5 mins.

The cycle given in Table 88 is based on the production of 150 denier Rayon at the rate of 2.25 pounds per spinneret per 24 hours. Compare this routing chart for the centrifugal-pot system with the one previously given for the bobbin method and at once the great saving of time in the pot method is apparent. This is due to the elimination of the twisting-time, which in the bobbin method takes 40 hours. In comparing the two operation cycles the time in the bobbin method is 82 to 84 hours while that in the centrifugal-pot method is 42 to 44 hours. This is just equal to the time necessary for twisting.

Following the above cycle the first operation, after the "cakes" are removed from the spinning machine, is:

Steaming or Humidifying.—This operation is necessary to prevent the threads in the cakes from becoming dry, which is very liable to cause (1) difficulty in rewinding, and (2) tendering of the threads. As the thread in these cakes still contains considerable acid coagulating solution, if the cakes are permitted to dry out this acid is concentrated in the thread, with a consequent tendering and destruction of the Rayon. It is necessary, therefore, to store the cakes in steam humidifying chambers.

Reeling and Lacing.—The cakes of Rayon thread are placed on reeling machines for conversion into skeins or hanks. See Fig. 99. As the Rayon threads are still wet and, therefore, have a very low tensile strength and elasticity, considerable care is necessary in this reeling operation, else the Rayon may be stretched to such an extent as to give uneven results in weaving or dyeing; or the individual filaments or even the thread itself broken. Some reeling machines carry as many as 6 or more skeins on a single reel while others are equipped with single or double hank reels, that is, reels carrying only one or two hanks. Reels of the latter type are shown in Figs. 101 and 102. These latter machines are claimed to

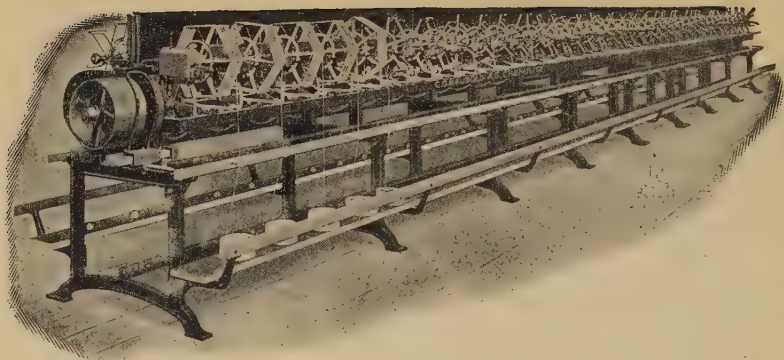


FIG. 99. Reeling Machine (from Cake). (Courtesy C. G. Haubold A. G., Chemnitz.)

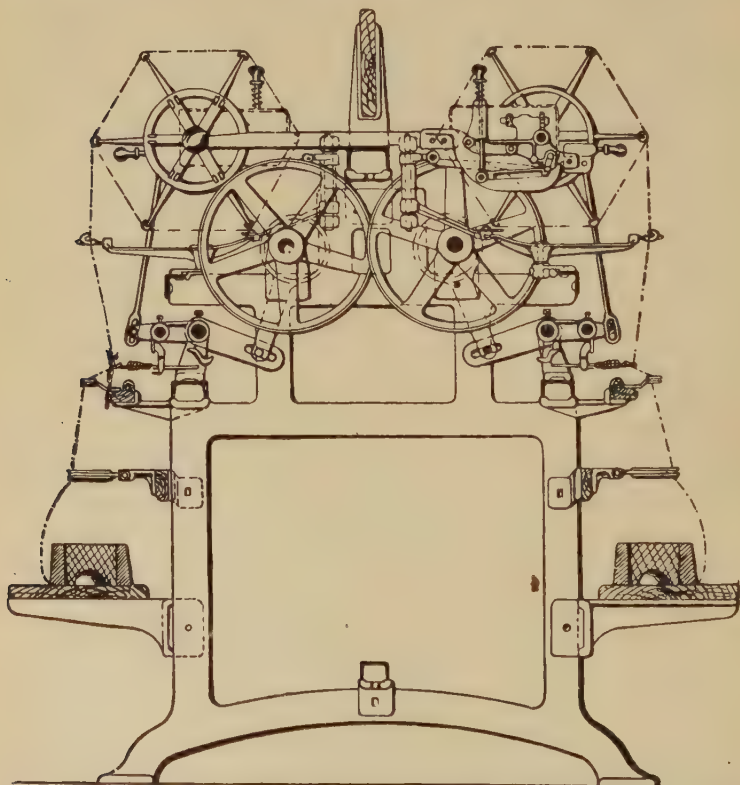


FIG. 100. Side Elevation of Reeling Machine (from Cake). (Courtesy C. G. Haubold A. G., Chemnitz.)

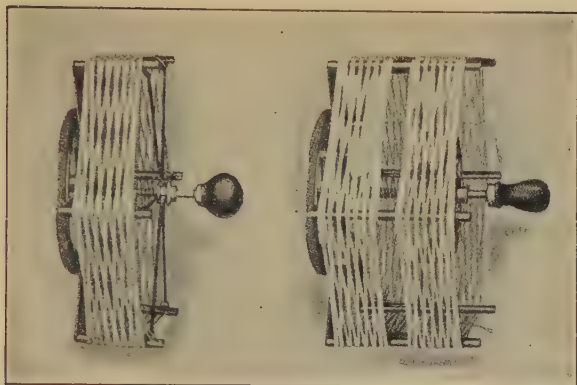


FIG. 101.
Single.

FIG. 102.
Double Skein Reel.
(Haubold.)

offer some advantages in connection with the removal of the skeins from the reels.

The reels usually run at a speed of about 300 R.P.M. and should start quickly but without jerking or subjecting the wet thread to undue strain. The thread is usually cross-wound on the reels, as shown in Figs. 101 and 102, so as to avoid tangling of the threads and give a skein of uniform circumference and length. The skeins are easily and quickly removed from the reels by a simple motion, as shown in Fig. 103, which places the skein on the arm of the operator. All reels are equipped with an automatic stop mechanism which stops the reel when the thread breaks. Some machines are also equipped with a counting and registering mechanism, so that the number of skeins produced on any one reel is automatically recorded.

Most reeling machines are designed for operation on both sides of the frame, as shown in Fig. 93. The frame should be sufficiently strong to prevent vibration of the moving parts, etc. As the cakes and skeins still contain the acid

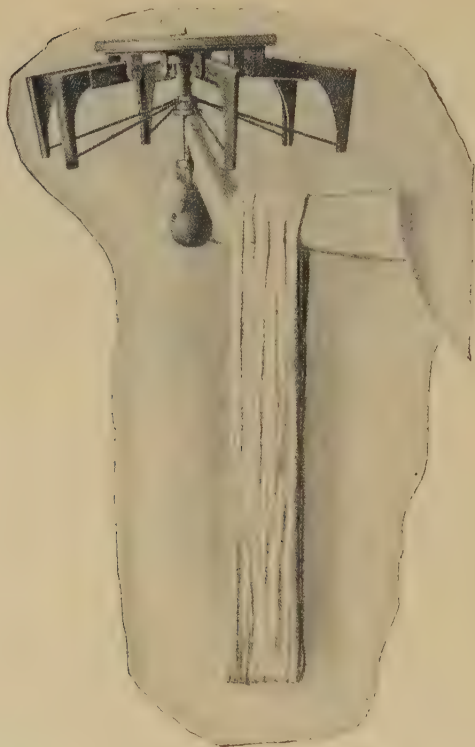


FIG. 103. Single and Double Winding Collapsible Reel. Haubold Design.

coagulating solution, all parts of the machine and reels should be resistant to acids. The reels are usually constructed of some light alloy and the bars supporting the skeins are sometimes coated with celluloid or a similar material. The machine shown in Fig. 99 is provided with screens to prevent movement of the threads, due to air currents from the moving parts, and with guard rails to prevent any accidental contact with the moving thread.

Depending upon the ability and skill of the attendants and the quality of the Rayon cakes, one person can usually attend to from 12 to 20 reels. With a 44-inch circumference reel,

the skeins are usually 1680 or 3360 yards in length. The skeins are cross-laced with either cotton, Rayon, or more seldom silk. These lacings are more or less evenly spaced around the skein so as to prevent any movement or tangling of the individual threads during the subsequent operations. Usually only four lacings are used and the common practice is to have one of these lacings dyed with a fast color, using a different color for each different denier of yarn, and tying each end of the thread to the colored lacing.

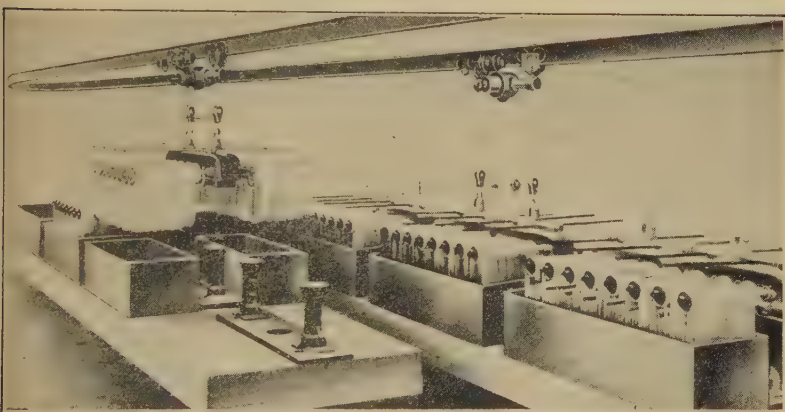


FIG. 104. Washing, Desulphurizing, Bleaching Machine. (A. U. Buhlman.)

Washing to Eliminate Acid.—As soon as the skeins are laced they are placed on glass, bakelite or rubber covered rods and washed free of all acid and salts remaining from the coagulating bath. This wash water must be free of calcium and iron salts and may be warm. If calcium is present, calcium sulphate may be precipitated within the yarn, and iron may result in yellowish or brownish stains in the Rayon, with time. The time required for washing depends upon the amount of water used, etc., but it is absolutely essential that all traces of acid and salts be removed from the Rayon.

The common practice was at one time to handle this washing, and the subsequent operations of desulphurizing, washing, bleaching, washing again, etc., by hand, but an automatic washing machine is now generally used, as was mentioned in connection with the handling of skeins from the bobbin spinning process. Figures 94, 104, 105, and 106 show such machines.

A recently designed machine is so arranged that the washing, desulphurizing, washing, bleaching, souring, washing, and drying all become a continuous operation. See Figs. 105 and 106. The skeins are placed on revolving rods which are fed through the machine progressively and longitudinally. As the rods revolve and move through the machine they pass under the several liquid tanks which are adapted to spray their solutions on the skeins, thus when the skeins are taken from the other end of the machine they are desulphurized, bleached and washed. The machine is designed to pass the rods from one section of the machine to the other automatically.

It has been learned in the industry that the less the Rayon is handled, especially when in a wet condition, the less the mechanical injury to the Rayon. Hence the machines of the type described in Figs. 94 and 105 revolve the rods, carrying the Rayon skeins so slowly and make such few revolutions in passing through the machine that the Rayon breakage is thought to be reduced to less than .25 of 1 per cent. The rods passing under the several sections are rotated in opposite directions, thus making the treatment uniform on the skeins, and at the same time the reversal of rotation has the tendency to eliminate "creeping" of the skeins as they pass through the machine.

Drying under Tension.—From the washing machine the skeins are placed under tension on frames known as stretching frames which are so designed as to permit tension to be applied to the aluminum rods on which the skeins are placed.

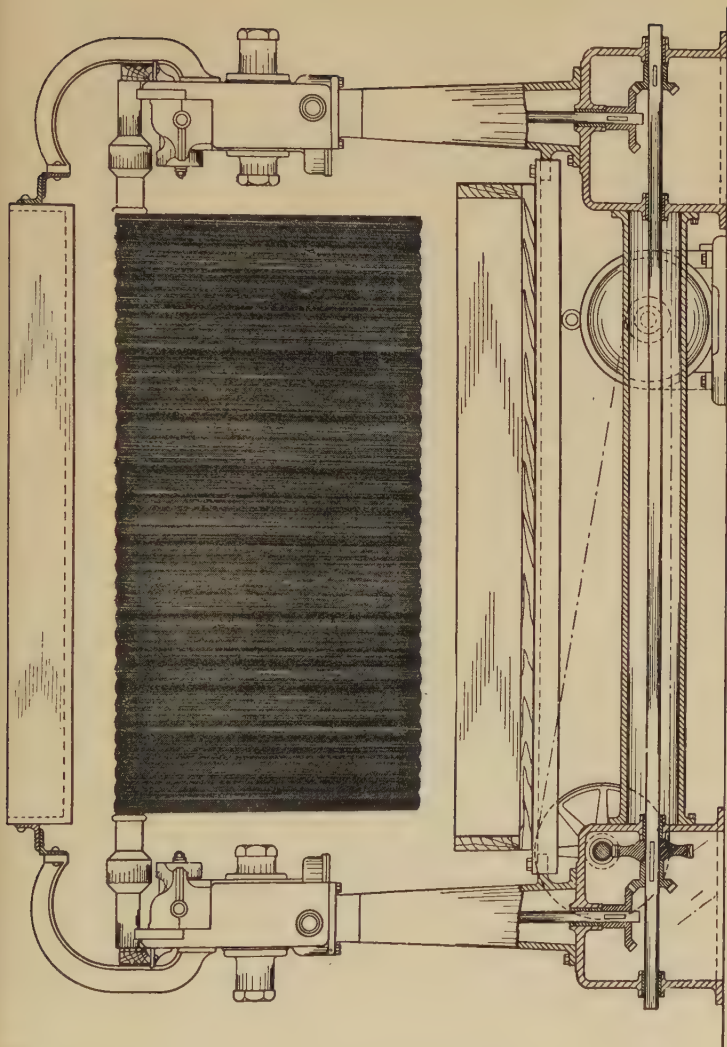


FIG. 105. Front View of Automatic Skein Washing, Bleaching and Dyeing Machine. (Courtesy Wm. W. McElrath.)

Figure 107 shows two rows of frames loaded with skeins under tension just as they are passed into the drying chamber. These tension frames are moved forward by chain conveyors through

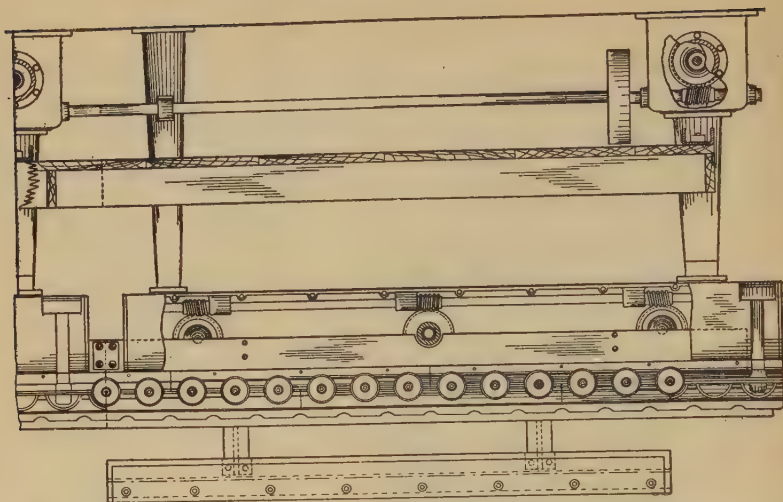


FIG. 106. Side Elevation of Washing Machine, Shown in Fig. 105 above.
(Courtesy of Wm. W. McElrath.)

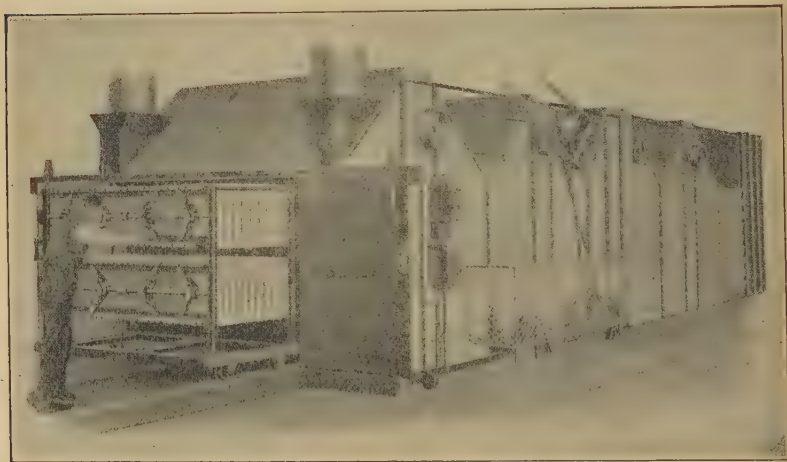


FIG. 107. Stretch Skein Dryer (Haas-Lenep).

the chamber while disc fans circulate the air, maintained at a temperature of 104 to 140 degrees Fahr., upon the skeins from the top to avoid entanglements of the skein threads. When

the tension frames reach the other end of the drying chamber the skeins should be dry. This tension of the frames has the following two effects:

- (1) The threads do not contract while the moisture is eliminated from the skein.
- (2) The simultaneous stretching and drying increases the luster of the Rayon.

After completion of the drying and stretching operations the skeins are removed from the frames and are now ready to continue the finishing processes in exactly the same manner as the bobbin skeins after reeling and lacing. The subsequent operations are given in the cycle as operations 7, 8, 9, 10, and 11. In both operating cycles, bobbin and centrifugal-pot spinning, these finishing operations are exactly the same and we refer the reader to the description of the consequent operations necessary for the centrifugal-pot skein to the treatment of the bobbin skein.

PLANT DESIGN FOR VISCOSE PROCESS

Site.—In determining upon a suitable site for a Rayon plant several important factors must be considered. Chief among these are the availability of a labor supply, water, waste disposal facilities, fuel, raw material and transportation facilities. Labor is the largest single item of cost in Rayon production. Not only must the amount of available labor be considered, but also the type and efficiency for this is a large factor in costs. More than half of the operatives are girls or women. Their work is the handling of delicate threads. Previous training in fine textile operations is an advantage but not essential. Furthermore, the cost of living should not be too high and the history of the locality should not show any grave labor troubles.

The water supply should be very carefully considered. A

Rayon plant producing approximately 2,000,000 pounds of Rayon per year (and this is not a large plant under present conditions) will require in excess of 1,000,000 gallons of water per day. This water preferably should come from artesian wells as this is generally the purest water. At least a portion of the total water necessary should be obtained from such wells and the balance from a lake or river of unfailing supply. Consideration should also be given to the possibilities of expansion and the resulting larger water requirements. Costs of bringing the water into the plant should be considered. The water should not be contaminated by waste from other factories or in any other way, else the necessary purification system may add a heavy item of cost. The water should also be as soft as possible. A softening system will be required in any event, but the softer the water in its raw state the less troublesome and expensive the softening operation becomes.

An amount of water equal to that brought into the plant must be disposed of into a drain or sewer. This water is contaminated by caustic soda, sulphuric acid and other chemicals. If these waste waters can be dumped into a sewer or river without any neutralizing process it is an advantage. In any event the waste waters must be disposed of and this disposal must be considered. Local restrictions may be so severe as to entail excessive expense.

A Rayon plant does not, comparatively speaking, require large quantities of power. Process requirements of steam for drying, warming water, etc., are, however, quite heavy. The plant should be located where fuel is available at a reasonable price and the matter of generating steam at high pressure for power and utilizing the exhaust steam for process requirements should be considered. Local costs for power should, of course, be compared with the costs of power so generated.

The transportation cost of raw materials used is a relatively small fraction of the total cost of the Rayon and in considering a site very little more need be kept in mind than the need of good railroad facilities and connections, including trackage into the grounds of the plant proper. The site of a Rayon plant should be selected with a view towards future expansion. It has been the practice of most producers of Rayon to house nearly all the departments in one-story saw-toothed buildings. Large areas of land are therefore needed. Not less than 50 acres of comparatively level ground should be available.

The problem of getting the finished goods to market is relatively unimportant. The nearer the market, the more ideal is the site, provided the other and more important factors are favorable. But the market is so broad that it does not seem that any great advantage can be won by nearness to any particular consuming center. Other factors in determining a site are such as may be termed local. The attitude of the community toward the proposed plant, taxation, banking facilities and other questions must be reckoned with under this head. A Rayon plant is established so as to produce goods that can be sold at profit, therefore any factor that adversely affects the cost of production should be considered as an unfavorable factor in selecting a location. No site should be selected unless it permits operation upon as favorable basis as any competing plants already in operation.

Economic Production Capacity of Plant.—Many of the questions covered in these pages on the economic production capacity of a Viscose Rayon plant have already been discussed in a general way, in behalf of all the processes in Chapter IX on Rayon Engineering Problems. It is, therefore, suggested that reference be made to that chapter for details as to certain phases of plant engineering which have not been covered here.

In considering the minimum size of a plant which would be profitable we are taking up a question still unsettled. The question should be considered from two angles, first, as one to produce Rayon for consumption within an existing knitting or weaving mill or group of textile mills. While very little information is available as to what scale of production results in a profitable enterprise, it is the author's opinion that the plant should have a capacity of approximately 2,000,000 pounds a year or three tons daily. Owing to the work of training labor, getting the plant tuned up and for other reasons, a start can be made on one-half or one-third of this capacity, provided plans are laid for expansion to the three-ton daily production basis.

The reason that this scale of production is so necessary, even at the start, lies in the fact that Rayon is such a highly specialized field. Exact control is necessary in every step. A highly skilled staff is absolutely essential. Another reason is the large outlay of capital needed for the plant. Approximately \$3,000,000 is required for the 2,000,000-pound plant, not including working capital. At least 50 per cent of the cash capital would be required to get a plant into commercial operation on the one-third production scale mentioned. The tendency at the present time, particularly of the larger Rayon mills, is to plan for five-ton daily or even greater production. Some plants represent an investment of \$7,000,000 to \$8,000,000, exclusive of the working capital. The same general staff is required for the smaller operation, and it is obvious that unless the larger production is quickly reached the staff overhead is higher than it should be.

Another factor that handicaps the small plant is the constant need for research. Rayon has been improved constantly since its inception and nearly all of these improvements have come from the research laboratories of the large manufacturers. This research work must go on and it re-

quires large scale operation to finance it. A small plant, therefore, finds itself at a disadvantage in this respect.

Let us consider another side of the question, namely the case where a knitting or weaving mill can use all the Rayon a small plant can produce. For some time this subject has been a matter of considerable discussion. The claim was recently advanced that any mill using 1000 pounds or more of Rayon per day could successfully and profitably produce its own supply. Several opinions to the contrary were quickly forthcoming. Nevertheless it is quite true that a plant using this quantity of Rayon per day would have a much better chance of success, on a small scale, than a plant that would be compelled to sell a small quantity in the open market.

A company formed to produce a small amount of Rayon for sale to others would be faced with an outlay for several items that a going textile concern could probably avoid. For example, the textile concern might have idle floor space that could be used for their Rayon production. They might have available an excess of power or steam. They would undoubtedly have an organization, including skilled textile operatives, from which they could recruit the needed Rayon producing personnel. The question of capital would likewise be simplified. Also, in using the Rayon in their own textile mill, handling and transportation charges and even some minor steps in the actual making of the Rayon itself might be saved. The critical cost point would be not what it costs other producers, but what it would cost them to buy Rayon in the open market, assuming the quality to be the same. However, they would still be faced with the same problem that faces every Rayon producer, namely, that of securing the necessary technical staff to operate the plant. In Europe where labor costs are lower than the United States weavers and knitters are operating their own small Rayon plants, for their own use, successfully.

Of equal importance is the question of what would be done with the Rayon producing unit if, through some change or depression in their own business, their consumption of Rayon should decline or even stop entirely. They might be faced with the necessity of going out in the market and selling their product, or of carrying on operations and storing the Rayon until they were able to use it; or else closing down the Rayon manufacturing plant and running the risk of losing the staff and personnel. Furthermore, it would be necessary to consider how and in what manner they could keep abreast with the rest of the Rayon industry; how they could conduct the extensive research work so essential to progress, etc.

Any one contemplating the manufacture of Rayon on a small scale to be used in his own textile mill will have to consider the case on its own merits, without having any general rules to follow. The possibility that in the future Rayon will be produced on a small scale may arise only through skillful engineering and designing, and proper correlation of machinery and equipment, through which means the present high costs of entering this field and the cost of production on a small scale will be reduced.

There is also the possibility of having several small Rayon plants operated by knitters or weavers to work cooperatively in order to keep abreast of the times, either by the pooling of technical knowledge, the interchanging of ideas, or perhaps by common support of a well-equipped research and control organization. Developments are expected along this line, for even now at least two cotton manufacturers are operating small Rayon units and more are projected.

In any event, when considering what the proper size of a Rayon plant should be it must be remembered that the initial production planned is only the starting point and full provision should be made for rapidly expanding the production program.

Layout and Design.—In laying out a Rayon plant for the Viscose process it will be well to follow the latest developments of present successful manufacturers. The chemical plant should be housed in a three or more story building and the spinning and textile operations carried on in a single-story, saw-toothed building. The chemical building is usually of reinforced concrete and should be well lighted. It must be designed in every detail with a view of the specific use to which it will be put. The saw-toothed building for the spinning department should have a special acid-resisting floor, of mastic or other suitable material, an insulated roof and double windows. Another important feature of the Rayon plant is the matter of air conditioning, and full provision should be made to cover this vital necessity.

The column spacing should be carefully considered, keeping in mind the type and size of the machines to be installed unless the latest design of spinning buildings of the saw-tooth roof construction be used without columns, such as have been built for the Viscose Company. These have a span of 100 feet in one direction and an unlimited length in the other direction without posts. A proper amount of head room must be provided as a considerable number of ducts are required to carry off the foul air and bring in a fresh supply. In most of the other saw-toothed buildings the needs are about the same as in the spinning room except that the floor does not need to be acid proof.

The floor areas needed for the different sizes of Rayon plants are approximately as follows:

One ton daily production, approximately. . . .	80,000 sq. ft.
Three tons daily production, approximately. . . .	180,000 sq. ft.
Ten tons daily production, approximately. . . .	500,000 sq. ft.

There being no load to be considered, excepting in the chemical building which takes up but a small proportion of

the entire area, these buildings can be erected economically and yet permit of proper air control. The latter is a prime requisite of such buildings.

Equipment.—The following is a list of the items of equipment by departments required for a Viscose Rayon plant centrifugal pot system:

1. *Cellulose Drying Plant.*
 - (a) Dryers.
 - (b) Board cutters.
2. *Mercerising Plant.*
 - (a) Steeping presses.
 - (b) Rapid scales.
 - (c) Disintegrating or shredding machines.
 - (d) Traveling cranes.
 - (e) Driving motors.
3. *Caustic Soda Dissolving Plant.*
 - (a) Tanks.
 - (b) Rapid dissolvers.
 - (c) Vessels for mixing caustic soda solution.
 - (d) Clearing tanks.
 - (e) Press feeding tanks.
 - (f) Caustic Soda pumps and driving motors.
4. *Aging Room.*
 - (a) Aging carriages.
 - (b) Aging cans.
 - (c) Temperature regulating equipment.
5. *Xanthating Plant.*
 - (a) Xanthate drums.
 - (b) Agitator barrels.
 - (c) Caustic Soda and water measuring tanks.
 - (d) Carbon disulphide plant.
 - (e) Carbon disulphide safety equipment.
 - (f) Electric motors, pumps and piping.
6. *Ripening Room.*
 - (a) Mixing tanks.
 - (b) Ripening tanks.

- (c) Piping for tanks, presses and pumps.
- (d) Filter presses.
- (e) Electric Motors for mixers and pumps.
- (f) Temperature control apparatus.

7. *Refrigerating and Engine Plant.*

- (a) Refrigerating plant.
- (b) Brine collecting tank and piping.
- (c) Pressure tanks.
- (d) Vacuum tanks.
- (e) Compressors.
- (f) Air pumps.
- (g) Driving motors.
- (h) Shafting in the engine room.

8. *Spinning Plant.*

- (a) Centrifugal (or bobbin) spinning machines.
- (b) Spinning motors.
- (c) Bakelite spinning boxes (or bobbins).
- (d) Filters, gooseneck pipes and spinneret holders.
- (e) Fume Suction plant, including fans.
- (f) Heating and humidifying plant.
- (g) Gear or piston spinning pumps.
- (h) Driving motors.
- (i) Suspension conveying plant for the spinning cakes (or bobbins)
- (j) Transformer plant.
- (k) Spinnerets made of gold-palladium, platinum alloy or glass.
- (l) Viscose and acid piping systems.

9. *Steaming Room for cakes.*

- (a) Air humidifying plant with fans.

10. *Precipitating Bath Room.*

- (a) Wooden tubs for mixing, storing, measuring and recovery.
- (b) Acid pumps (of earthenware) and piping.
- (c) Driving motors.
- (d) Acid filters "Silex."
- (e) Acid storage tanks.
- (f) Scales.

11. *Reeling Plant.*

- (a) Reeling machines.
- (b) Driving motors.
- (c) Lacing frames.
- (d) Complete humidifying plant, including motors.
- (e) Complete heating plant.
- (f) Celluloid sheets to be placed inside the spinning cakes.

12. *Washing Plant.*

- (a) Washing machines.
- (b) Pumps (these are only required if not sufficient pressure is available).
- (c) Driving motors.

13. *First Drying Plant* (drying under tension).

- (a) Automatic conveyor drying plant with tension carriages.
- (b) Motors.

14. *Bleaching Plant* (desulphurizing, washing, bleaching, souring and washing).

- (a) Wooden tubs.
- (b) Iron tubs.
- (c) Frames.
- (d) Traveling cranes.
- (e) Suspended direct electrically driven hydro-extractors.

15. *Second Drying Plant.*

- (a) Automatic conveyor drying plant with carriages.
- (b) Electric motors.

16. *Assorting Room.*

- (a) Assorting frames.
- (b) Humidifying plant with heating plant and motors.
- (c) Yarn testing apparatus.

17. *Packing Room.*

- (a) Bundling presses.
- (b) Driving motors.

18. *Pipe Lines.*

19. *Laboratory.*

- (a) Laboratory centrifugal spinning and reeling machine.
- (b) Microscopic apparatus.
- (c) Driving motor.
- (d) Chemical testing apparatus.
- (e) Physical testing apparatus.

20. *Water Plant.*

- (a) Motors and pumps.
- (b) Pre-treatment system.
- (c) Zeolite softener.
- (d) Sewage disposal.

For the bobbin method the bobbin spoolers and twistors would be required.

Europe has made greater strides in the building of standard Rayon equipment for general sale than has the United States. In Germany and in England there are at least a dozen builders of spinning machines, several that make a specialty of complete plant equipment and many others that specialize on spinning pumps, steeping presses, mixers, xanthators, etc. In this country most of the equipment has been built to specifications furnished by the individual Rayon producer. Two companies have recently started the building of spinning machines and the future will see others entering this field. With proper cooperation between machine builder and Rayon manufacturers standardized lower-priced and better equipment should be possible.

Capital Requirements.—We will assume that 110 plant should be planned for making Rayon by the Viscose process with less than one-ton capacity daily, based on an average size of 150 denier yarn. Further, that provision be made for quick and easy expansion as soon as a labor force can be properly trained to a point where the added equipment can

be manned. For such a plant there should be available not less than \$1,800,000, including working capital.

The complete cost of a plant to produce three tons of Rayon per day will be approximately \$3,000,000, not including working capital, for which should be added \$500,000. These figures presume careful planning and organization and do not allow for any costly mistakes or excessive cost for capital. If operations are successful on such scale production, and capacity quickly attained, it should be possible to increase production for about \$350,000 for every 1000 pounds of daily capacity, provided the original plans of the first unit took into consideration the question of enlargement by the addition of partial equipment in various departments of the plant. These figures are approximate only and they will vary with the location of the plant and other controlling factors.

Cost of Land.—It is not possible to give any limiting figures for the land since this will depend upon location, amount of land purchased and other conditions, but, of course, land value should be kept as low as possible.

Buildings.—The building necessary to house a Rayon plant of three tons' daily capacity should have approximately 160,000 square feet which at the rate of \$3.75 per square foot will cost approximately \$600,000. This figure should cover sprinkler systems, heating, plumbing, lighting, roof insulation and double sash where needed, and special acid-proof floor where required. This figure will vary with prevailing building costs in different sections of the country. No process piping or air conditioning system is included in this estimate.

Equipment.—The various items of equipment needed to produce three tons of Rayon per day, as listed in the preceding pages, will cost approximately \$1,000,000 which will cover duty on that portion of the machinery which must be imported

into the United States, also freight, packing and installation. It will vary somewhat with the type of equipment purchased and the location of the plant.

Power Plant, Motors, Etc.—To provide the power and refrigeration plants, motors, wiring, process piping, air conditioning and other necessary items, about \$550,000 more will be needed.

Other Items.—For the remaining items of expense such as engineering and other contingencies \$350,000 should be provided.

As a résumé of capital requirements for the construction and operation of a Viscose Rayon plant the following table is offered:

Plant Capacity, 3 Tons Per Day

1. Buildings and land as specified above.....	\$600,000
2. Equipment as listed and specified.....	1,000,000
3. Power plant, motors, wiring, process piping and air conditioning.....	550,000
4. Installation, engineering expense and con- tingencies	350,000
Total Cost of Plant.....	\$2,500,000
5. Working Capital	500,000
Capital Investment.....	\$3,000,000

Manufacturing Costs.—The cost of producing Rayon in the United States by the Viscose process depends upon several factors, chief of which are the size of the plant, its location, and denier of Rayon produced. Few cost figures are available from successfully operating plants. Cost figures can be obtained by an analysis of materials, labor and overhead.

Labor.—For a plant of 3 tons' daily capacity approximately 1000 employees for the 3 shifts are needed, of which 50 per cent could be female labor. The labor item for a plant

of this capacity averages about 42 per cent of the total cost of making a pound of Rayon. The material cost averages about 25 per cent based on a material cost of from 18 to 20 cents, thus giving us a labor cost of from 38 to 45 cents.

Materials.—The cost of material for a pound of finished Rayon approximates about 25 per cent of the total cost of a pound of finished Rayon and ranges between 22 and 26 cents per pound. This is figured on a basis of one and one-half pounds of pulp, two pounds of caustic and six-tenths pound of carbon bisulphide per pound of finished Rayon. Other materials in smaller quantities are required, but these are the principal items of expense. Figures recently received from Germany show a cost for materials of 48 cents per kilo of finished Rayon or approximately 22 cents per pound.

Overhead.—About 32 per cent of the total cost is covered by the overhead which includes administration and engineering staff, water, fuel, light and power, insurance, taxes and depreciation, supplies and repairs. The overhead item, therefore, is about 28 cents.

On the basis of the above statements the cost per pound of finished Rayon will be from 80 cents to \$1.00. Figures obtained from Germany show total cost per pound of Rayon of about 62 cents: with material taken at 22 cents, wages at 24 cents and overhead 20 cents.

In order to accurately determine the cost of production in a proposed or existing Rayon plant, it is necessary to first fix accurate values upon the many usually variable factors, such as the cost of the location and plant, raw materials including fuel and water, transportation, type and cost of labor, as well as numerous other items. In Chapter IX on Rayon Engineering Problems a percentage distribution of cost per pound of Rayon is given. This is repeated below for convenience in comparing it with the figures discussed in the paragraphs on Materials, Labor, and Overhead, above.

PERCENTAGE OF COST COMPUTED FOR A CAPACITY OF 3 TONS DAILY

I. Raw Materials:

(a) Alpha Sulphite Pulp, 4½ Tons	} 25% of total cost per pound.
(b) Caustic Soda (NaOH), 6 Tons	
(c) Carbon Bisulphide, 1.8 Tons	

2. Labor: approximately 1000 workers required for the 3 shifts.

Male Labor, 40 to 50%	} 43% of total cost per pound.
Female Labor, 50 to 60%	
Female, working only 1 and 2 shifts on the reeling and grading oper- ations.	

3. Overhead:

(a) Engineering staff and adminis- tration, 10%	} 32% of total cost per pound.
(b) Water, fuel, light and power, 6%	
Fuel required, 50 tons coal daily	
(c) Insurance, Taxes and Depreci- ation, 10%	
(d) Supplies and Repairs, 6%	}
Total for Overhead	

Total 100%

If the above ratio of costs can be maintained, figuring on a basis of material cost at 18 cents per pound of Rayon, total cost of the Rayon will be 81 cents per pound. This allows 38 cents per pound for labor, and 25 cents per pound for overhead.

From a study of the above figures it appears that the easiest method of reducing the cost of the Rayon is to reduce the overhead, and this is best done by increasing the production of the plant. Beyond this, any further reduction in costs must come through increased efficiency in the plant and from

the labor, improved equipment, and economies effected by purchasing large quantities of raw material. The cost of Rayon to the very large companies is for reasons just indicated considerably lower than 88 cents per pound.

IMPROVEMENT TENDENCIES

Rayon companies now successfully operating have large staffs of skilled technicians constantly at work seeking to improve quality, manufacturing methods, and trying in every way to add to the present knowledge of the art. Considerable research work has been conducted in the study of the aging of the alkali-cellulose. While the aging of the crumbs is controllable, the scientific reason for the reactions taking place during this aging process is still more or less unknown. Aside from the scientific value of this work, it is of great practical value, for the aging of the alkali-cellulose crumbs requires from two to three full days, and means a large investment in floor space, cans and materials, that would be reduced if this time could be shortened. A great deal of research has also been conducted upon the ripening process.

Another fertile field for research, which has been the subject of much study for a long time, is the precipitating bath. There have been many materials suggested from time to time to improve this phase of the process, and this field is receiving its share of attention. The washing process is also open for improvements. The acid has always been very difficult to completely remove and therefore requires considerable floor space, particularly for the bobbin spinning method which requires many bobbins and large quantities of water. The rotary washing machine mentioned before seems a distinct advance in the saving of time, floor space and water.

A machine recently developed in Germany combines in one continuous operation washing of the bobbins, twisting

and reeling. Very interesting claims are made for it, although commercial operation has not as yet proven its value. It is, however, an indication of the constant attempts which are being made to improve and shorten the bobbin process. The centrifugal-pot spinning method has proven an advance in shortening the time of production, since the rapidly spinning pot does the twisting, thus saving the twisting machine operation necessary in the bobbin method. The machine which desulphurizes, washes, bleaches, sours and again washes through a continuous process is also a new development saving considerable in cost of operation for both the bobbin and pot methods.

Another new piece of equipment has been brought out that combines in one operation both xanthating and solution mixing, but this is still a laboratory sized machine. It is understood, however, that in one of the laboratories in Germany shredding, xanthating and solution mixing is being carried out in one of these machines without any aging of the alkali-cellulose crumbs. It is not possible to say at this time whether any positive results are being obtained.

Among improvements in the quality of the yarn itself, we find the multifilament finer denier yarns. This is a distinct advance and demand for this improved quality is increasing. It adds softness, pliability and greater covering power to the yarn, although it is claimed that these qualities are achieved only at the sacrifice of durability. The fact remains, however, that these yarns usually command a premium, the "Super Extra" bringing an advance of about 60 cents per pound over the market price for 150 denier yarn of regular quality. Another fact is that nearly every company now making Viscose Rayon is working on these yarns of higher filament number. Certain imported yarns claim 110 filaments for the 150 denier size and one company in the United States proposes to produce 150 filaments for the 150 denier yarn.

In the fineness of the count we also find progress. We find a Viscose yarn of 75 denier quoted by at least one manufacturer. A European firm claims to be producing a 20 denier yarn with fifteen filaments. It has usually been claimed that the Viscose process could not make the finer sizes, but this view seems to be giving way before the facts. The improved strength of the yarn when wet is another tendency rapidly taking effect. One result of this increased strength of Rayon yarn is in its increased use by the underwear manufacturer. There has been considerable development proceeding in this direction, particularly in the Lilienfeld process.

CHAPTER XII

THE CUPRA-AMMONIUM PROCESS

History.—The cupra-ammonium process was first proposed by M. Despeissis, a Frenchman, who applied for French Patent No. 203,741 in 1890, but died before the patent was finally completed or granted. The process was later taken up by Pauly and Bronnert, as well as Linkmeyer, Fremery, Urban, Thiele, Foltzer, and many others, who have greatly advanced the art to the present commercial success. It is claimed that Pauly was the first to use this process commercially. The first commercial success was at Gladbach, and this led to the development of the German "Glanzstoff." The number of plants at present using this process and the total quantity produced, is quite small as compared with the Viscose process. The largest American producer is the American Bemberg Corporation at Johnston, Tenn., but several other small American plants are either experimenting with this process or are producing some Rayon. Cupra-ammonium Rayon is also produced in numerous plants abroad but by far the largest producer is the J. P. Bemberg A.-G. of Barmen, and associated companies. Cupra-ammonium Rayon is claimed to have some advantages over Viscose Rayon.

Raw Materials.

The raw materials used are the following:

(a) In this process cotton is the principal source of cellulose, but recently specially purified sulphite wood pulp has also been used successfully. The cotton is generally in the form of linters, but cotton waste has also been suggested as suitable.

The chemicals used in the purification of the linters are:

- (b) Caustic soda or sodium hydroxide (NaOH).
- (c) Sodium carbonate (Na_2CO_3).
- (d) Bleaching chemicals, such as chlorine gas or bleaching powder.

For the preparation of the cupra-ammonium solution:

- (a) Metallic copper (Cu), or
- (b) Copper sulphate (CuSO_4) and
- (c) Sodium hydroxide or carbonate (NaOH or Na_2CO_3)
- (d) Aqueous ammonia or ammonium hydroxide (NH_4OH), commonly called ammonia.

For the coagulating bath:

- (a) Sulphuric acid (H_2SO_4), or
- (b) Caustic soda (NaOH)

Besides the above materials there are those used in the finishing processes and the water, the purity and quantity of which are just as important as in the case of the Viscose process, the chemistry of which was discussed in the chapters on Rayon Engineering Problems and Principal Raw Materials.

STEPS IN THE PROCESS

The principal steps in the manufacture of cupra-ammonium Rayon are the following:

- A. The purification of the raw material—cotton.
- B. The preparation of the spinning solution.
 - (1) From Cupra-ammonium solution, or
 - (2) From copper hydroxide and ammonium hydroxide, or copper carbonate ammonium hydroxide solution.
- C. Spinning the solution.
- D. After-treatment of the spun thread and finishing.
- E. Recovery of chemicals.

A. *Purification of the Raw Material.*—The purification of the cotton, either in the usual form of linters, or as cotton waste or raw cotton, is usually very much the same for any Rayon process, either cupra-ammonium, Viscose (where linters are used), nitro, or acetate. Therefore, this phase of Rayon manufacture will be covered here for all of the processes. As practically all of the cotton used in Rayon manufacture with the exception of Viscose Rayon, is in the form of linters, the very short fibers removed from the cotton seed after the usual ginning operation for the removal of the usual longer cotton fibres, special attention will be given to this particular form. Only minor changes in the process are necessary in handling raw cotton or clean cotton waste.

The cotton linters are received in bales weighing approximately 500 pounds. These bales are very tightly compressed and the first step is to open up this mass. For this purpose a bale breaker is used. This breaker automatically tears open the mass of linters by means of a revolving drum equipped with sharp teeth which shred the material into a uniform and fluffy condition. Care must be taken in this operation as there is quite a fire hazard unless the cotton is blown or conveyed to a storage room.

The impurities in the linters may be grouped into two classes; (1) mechanical and (2) chemical, according to the methods of their removal. The mechanical impurities consist of sand and dirt, bits of cotton plant stems, cotton seed hulls, etc. These are largely removed by the mechanical treatment of the opening process. The chemical impurities largely consist of oils, fats, waxes, pectin and protein matter, etc. These are very little affected by the mechanical process of opening but require a chemical treatment for their removal.

The opened linters are weighed into lots of a size suitable for the open or closed tank, usually called a "kier," to be used in the boiling out process. This "kiering" process varies

widely with the character of the raw material, the impurities present, and the result desired. Sometimes an open kier is used and the linters boiled at atmospheric pressure with 6 to 10, or even more, times their weight of an alkaline solution. More often they are boiled in a closed kier under a pressure of 10 to 20 pounds per square inch, for from 4 to 10 hours with a constant circulation of the linters or hot liquor. See Fig. 108.

The alkali used may be either sodium carbonate (soda ash) or sodium hydroxide (caustic soda), but more often a

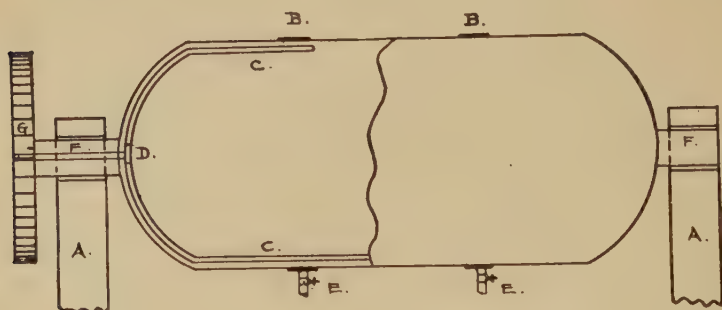


FIG. 108. Side Elevation of Rotary Kier.

mixture of the carbonate and hydroxide is used. The amount of alkali necessary also varies widely, but as a rule not less than 2 per cent nor more than 5 per cent, on the weight of the linters and not on the volume of the solution, is used. The weighed linters are placed in the kier, the alkaline liquor added, the top closed if a pressure kier is in use, and the circulating system started. Heating continues during the entire boiling time, or until near the end of the boil, when the pressure is allowed to drop before the kier is opened. After the kier is opened, the linters are rinsed and centrifuged first with hot and then with cold water, see Fig. 96, and are then ready for bleaching.

In order to eliminate manual labor just as much as possible in handling the linters, several devices have been adapted. In one of these methods, the whole kier is mounted on trunnions so that it can be tipped over to discharge its contents. By another process, a perforated basket in the kier holds the entire charge of linters during the boil. Upon completion of the process, this basket is lifted from the kier by means of an overhead crane arranged on an overhead trolley system. A removable bottom on the basket permits the entire charge to be dumped in one movement.

For bleaching, a sodium hypochlorite solution is commonly used. The chlorine is generally received in cylinders and the sodium hypochlorite solution prepared by passing this into a solution of caustic soda or a mixture of caustic soda and soda ash. Bleaching powder (calcium hypochlorite) is also used in bleaching linters but the sodium compound is usually preferred so as to avoid difficulty in the elimination of lime compounds from the cellulose later in the process. The extent to which the bleaching is carried varies somewhat with the nature of the process of manufacture to be used, that is, whether the linters go into the cupra-ammonium, nitro, or acetate process. The bleaching is conducted at a low temperature.

The linters are usually bleached in a concrete tank or pit, although wood or stone is sometimes used in parts of the construction. The bleach liquor is circulated through the mass of linters, considerable care being necessary here, just as in the kieren process, to see that no channelling occurs with a consequent uneven treatment of the cellulose. Where overbleaching and under-bleaching occurs in spots, a defective Rayon is sure to result. Strict chemical control is exercised over the entire bleaching operation as the results obtained in this process considerably influence the properties of the Rayon spinning solution and, therefore, the properties of the

finished Rayon. Without uniform bleaching, a uniform Rayon is impossible. See Fig. 109.

When the linters have been bleached to the desired degree,

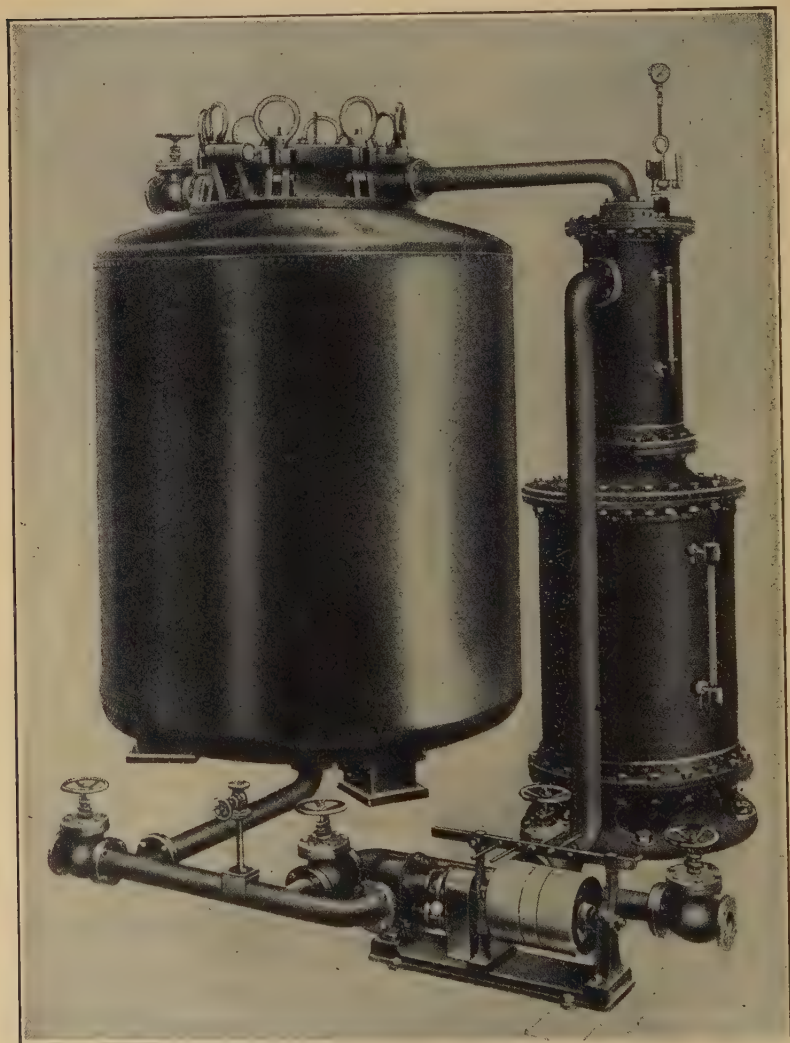


FIG. 109. Boiling Kier (C. G. Haubold A. G., Chemnitz).

the bleach liquor is drained off, or they are removed from the bleach tank, and are "soured" with a dilute solution of sulphuric acid, to decompose any hypochlorite bleaching solution remaining in the fibres. They are next rinsed until free of all traces of both the bleach liquor and acid, and centrifuged or pressed to remove as much water as possible.

The bleached linters are usually dried in an automatic dryer of the continuous type. An automatic feeding device conveys them to a moving apron, which carries them through the drying chamber. These dryers are equipped with the usual heating coils and air-circulating fans. By proper regulation of temperature, time, and speed of air circulation, the linters contain just the desired degree of moisture upon leaving this dryer. They are usually stored in sheet iron boxes, in a room of proper temperature and humidity so as not to alter their moisture content, until needed for solution.

In actual practice the Rayon producer often buys the cotton ready for solution, expecting from the bleaching guaranteed limits of grease, ash, and moisture content. The combined grease and ash should not exceed 0.4 per cent and the moisture not more than 6 per cent. The amount of hypochlorite used in bleaching should also be known.

B. *Preparation of the Solution.*

(1) The Cupra-ammonium Solution.

The cupra-ammonium solution is prepared in four ways (*a*) by the action of ammonia (ammonium hydroxide solution) on metallic copper in the presence of air; (*b*) by the combined action of ammonium and sodium hydroxides upon a copper salt, such as copper sulphate; (*c*) by the solution of previously prepared copper hydroxide or carbonate in the ammonia solution; and (*d*) by the action of the ammonia solu-

tion on a mixture of the copper hydroxide or carbonate with the cellulose.

(a) The early method of preparing the cupra-ammonium solution requires considerable time, being controlled largely by the strength of the ammonia solution used, the physical condition of the copper which is usually in the form of turnings, temperature, etc.

These copper turnings are packed in a special cylinder provided with a jacket for the circulation of a cooling solution, so as to control the temperature, and the ammonium hydroxide solution added. Air is forced through the liquid in the cylinder, forming the copper oxide or hydroxide, which is dissolved by the ammonia. The temperature is usually maintained below 41 degrees Fahr. by the circulation of the cooling brine in the jacket of the cylinder and the preparation of the solution, by this process, usually requires from 12 to 20 hours. The blowing with air may be either continuous during this time or intermittent.

Figure 110 shows one of these solution cylinders. The copper is entered through *B* and the ammonia through *C*. After closing *B* tightly, the air is forced into the cylinder through *R* at about 30 pounds pressure, passing out through *C* to a tower or other absorption apparatus for the ammonia fumes. The exact composition of the finished solution varies in different plants but usually contains about 3 to 3.5 per cent of copper and 25 per cent of ammonia, with a specific gravity of about 1.004. It is allowed to pass through *D* into a suitable storage or measuring tank.

(b) By a somewhat later and better method the cupra-ammonium solution is prepared by the action of a mixture of sodium and ammonium hydroxides on a copper salt, such as copper sulphate, instead of from the metal itself.

(c) Another method, which is now in common use, consists of two steps in the first of which the copper is prepared

for solution by precipitating a copper salt, usually the sulphate, from its solution by means of sodium hydroxide or carbonate. This precipitate is washed free of salts and then dissolved in the ammonia solution of suitable strength. As in each of the above methods, *a*, *b*, and *c*, the temperature of the process is carefully controlled by the use of jacket vessels, cooled by a brine circulating system. The usual temperature is about 40 degrees Fahr.

Where the solution of the cellulose and preparation of the cupra-ammonium solution do not proceed simultaneously, as described in *d*, a definite quantity of the purified cellulose is treated in a jacketed mixer with a measured volume of the cupra-ammonium solution at about 40 degrees Fahr. to produce a spinning solution containing 8 to 10 per cent of cellulose. Figure III shows a mixer of the type suitable for this purpose. The cupra-ammonium solution is placed in the mixer, together with a small amount of sodium hydroxide. After stirring this for a minute or two, the cellulose is entered through the manhole,

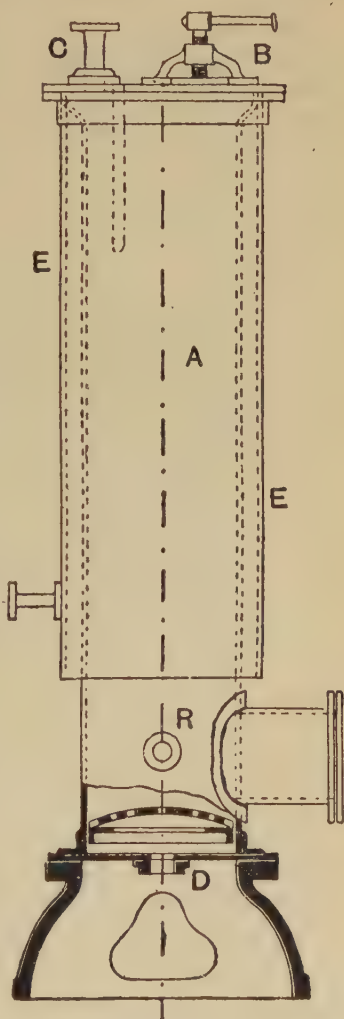


FIG. 110. Cupra-ammonia Solution Cylinder Producer. (Courtesy Foltzer.)

which is then closed and the agitator started, rotating at about 6 R.P.M. The action of the agitator serves somewhat the same function as the shredder used in the Viscose process and aids materially in the solution of the cellulose. Agitation is continued until the cellulose is completely dissolved and the solution has the desired characteristics. This requires as much as 24 hours but usually less time. The mixer is air tight but is equipped with a suitable hood and suction fan to carry off the ammonia fumes when it is opened.

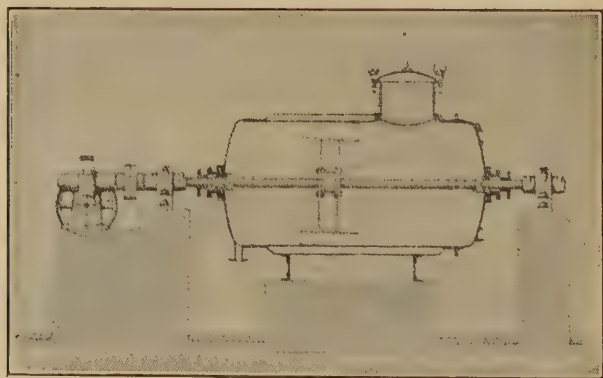


FIG. III. Cupra-ammonium Cotton Solution Mixer. (John Hetherington & Sons, Ltd., Manchester.)

One of the quickest control tests on the cupra-ammonium cellulose solution is that of viscosity but chemical tests are also conducted on the finished solution.

(d) By an alternative method, the copper hydroxide or carbonate is prepared as in *c* above and this, in the form of pulp, is intimately mixed with the cellulose at about 80 degrees Fahr. in a machine of the shredder type. This mixture goes to a hydraulic press where the salts are washed out. The copper-cellulose cakes are then mixed for some hours in a suitable

machine at 32 to 40 degrees Fahr., with an aqueous solution of ammonium hydroxide, containing some sodium hydroxide and usually some organic material such as glucose or lactic acid, until solution is complete and the desired characteristics are obtained. This method of preparation is particularly used in connection with the stretch spinning process which is described later in the chapter.

The preparation of this solution is of great importance and exact chemical control is necessary to insure a spinning solution that will contain the correct percentage of cellulose, of the desired viscosity, and otherwise have all of the required spinning qualifications. After the solution has been prepared it is withdrawn from the mixer through large openings in the bottom of the machine and pumped into an iron storage or holding tank. This tank is provided with a compressed air connection for driving the solution to the filter presses.

Filtration.—From the storage tank the solution is forced by means of compressed air through a filter press (Fig. 112) provided with monel metal, iron or nickel screens of a very fine mesh ranging from 150 to 200 mesh per square inch. In constructing the filter press care must be taken to use only metals that will not be attacked by the ammoniacal solution.

The filtration of the spinning solution is fully as important in the cupra-ammonium process as it is in the Viscose process and precautions must be taken to free it from all particles of foreign matter, undigested cotton, or any other substances that may block the tiny holes in the spinnerets. It may be necessary to repeat the filtration several times to achieve the desired result. Centrifugal filtration has also been used in the cupra-ammonium cellulose solutions to some extent.

In this method the solution is brought to the centrifuge by means of compressed air, forced into the feed intake at the bottom of the centrifuge bowl, and carried up through the

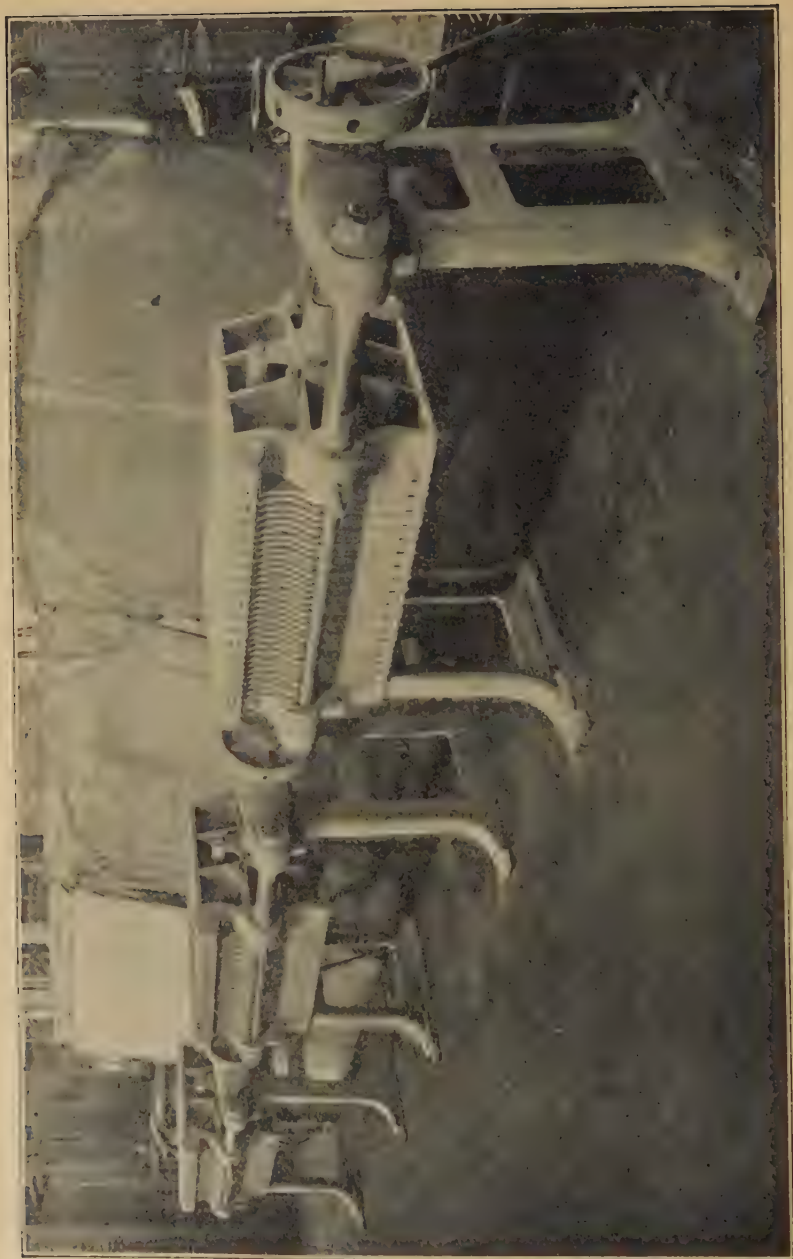


FIG. 112. Filter Presses (D. R. Sperry & Co.)

bowl, which rotates at from 13,000 to 17,000 R.P.M., by the centrifugal force at the revolving bowl.

Under the influence of the centrifugal force exerted the particles of dirt and other foreign matter are forced to the side of the bowl and held there, while the solution is carried on up through the bowl and out into the discharge line, which conveys it to a storage tank. The process is usually repeated two or three times, or until complete filtration has been accomplished. The filter-press method seems, however, to continue in favor. Hoods must be provided over each centrifugal to carry off the ammonia fumes. The metal used in the centrifugal must also be proof against the action of the ammoniacal solution.

After filtration the solution is held in tanks until required for spinning. Glass-lined tanks are generally used to prevent any foreign matter from entering the solution. These tanks are fitted with gage glasses, inlet and outlet lines for the solution, as well as for compressed air and vacuum. During this holding period the gas bubbles must be removed from the solution to prevent breaks in the filaments at the spinnerets. A vacuum can be employed, but it must be very carefully controlled because of the volatile nature of the ammonia in the solution.

Just as in the case with most of the other cellulose spinning solutions, this cupra-ammonium cellulose solution is not as stable as might be desired, certain changes occurring with time. In order to stabilize this solution as much as possible it is, therefore, common practice to maintain the temperature very low and to add certain organic hydroxy compounds to it. Numerous compounds are suitable for this purpose but glucose is most commonly used. Other sugars, starch, glycerol, tartaric, citric and oxalic acids, etc., may also be used. The stability is sometimes further increased by the addition of caustic soda.

C. Spinning the Rayon.—The process used in spinning the cupra-ammonium cellulose solution into Rayon is very similar to that used in the bobbin method of spinning Viscose silk. More recently, however, the centrifugal or pot spinning process has come into use in the spinning of cupra-ammonium Rayon also. The spinning solution is forced from the storage tanks into the distributing pipes and as far as the pumps on the spinning machines by means of compressed air. The pumps then force the solution through the spinnerets, which are usually of glass or nickel. In the pot stretch spinning method, no spinning pumps are used, the solution being forced through the spinnerets by pressure only.

Glass or metal bobbins are generally used in the cupra-ammonium process. Where the pot method is used, the gathering is the same as in the Viscose process. The spinning machine must give a constant and uniform supply of solution per unit of time, and have an accurate winding system. The machine must be so built as to withstand the solutions employed and in most respects it very closely resembles the machines used in the Viscose process.

Spinning Bath.—The spinning, precipitating or coagulating bath may be either an acid (usually sulphuric) or alkaline (usually sodium hydroxide) solution. The earlier processes all used the acid coagulating bath but the later developments include an alkaline coagulating bath. A still more recent development includes the use of two spinning baths. This latter method is used particularly in the stretch spinning process.

Where the single acid spinning bath is used, a much stronger solution of sulphuric acid is generally necessary than in the spinning of Viscose silk. The early patents along this line specified a spinning solution containing 30 to 65 per cent of sulphuric acid, by volume. Later improvements included the use of more dilute acid solutions, as well as those containing bisulphates and various other salts. This acid solution neu-

tralizes the ammonium hydroxide present in the spinning solution, thus causing the precipitation of the cellulose and copper, that is, that part of the copper which is not dissolved by the acid precipitating solution.

The Alkaline Spinning Bath.—The composition of the alkaline spinning bath also varies considerably in different plants and processes. The sodium hydroxide content is not usually less than about 5 per cent, in which case a second bath of stronger alkali or an acid bath generally follows, and may run as high as 30 per cent of alkali. Frequently it also contains other materials, such as glucose or other hydroxy compound. The principal use of the more dilute alkaline spinning baths is in connection with the stretch spinning process, as will be described later. While the temperatures used vary in the different plants, it is carefully controlled in each plant by means of accurate automatic control apparatus and coils in the storage tanks feeding the spinning machines.

Cupra-ammonium Rayon produced by alkaline precipitation differs considerably from the acid precipitated product, in that it is usually stronger, less brittle, more milky, duller and less transparent, which means a greater covering power. The alkaline bath also offers the advantage of being easier to control but results in some difficulty due to the evolution of ammonia fumes, which must be removed and recovered from the air.

The Two Bath Method.—As mentioned above, two coagulating or spinning baths are sometimes used. In this process the thread is usually only partially coagulated in the first bath, which may be a dilute acid solution but more often consists of about a 5 per cent caustic soda solution. The thread then continues on to the second coagulating bath, but it is stretched to a definite extent before it enters this second bath, where complete coagulation occurs, either by means of an acid or alkaline solution.

Stretch Spinning.—A variation of the cupra-ammonium process employed to produce very fine filaments and deniers is the so-called “stretch spinning” method. The spinning solution is forced through the spinnerets by air pressure and into a mild spinning bath that only partly hardens or coagulates the spinning solution as described above. In this somewhat plastic state the filaments are drawn or stretched to the required fineness. These filaments are gathered in a centrifugal pot. By

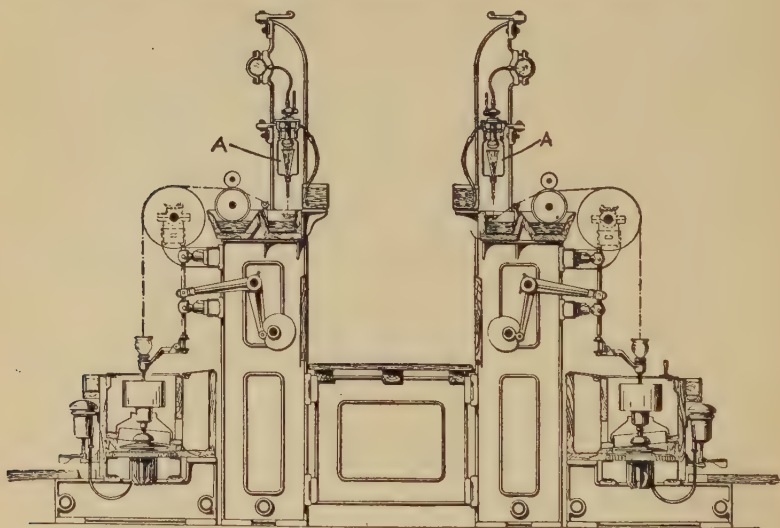


FIG. 113. Centrifugal Pot Spinning Stretch Method. (Courtesy C. G. Haubold A. G., Chemnitz.)

this stretch spinning method very fine denier filaments are produced. (Fig. 113.)

As early as 1902 Dr. Thiele succeeded in producing individual filaments as fine as 0.5 to 0.6 deniers, on an experimental scale. More recently these very fine filaments have become available on a commercial scale.

While the first stretch spun cupra-ammonium Rayon was produced on bobbin spinning machines, somewhat similar to

those used for Viscose, a more modern spinning machine utilizes the pull of a falling column of the dilute spinning solution to stretch the filaments before they are completely coagulated.

The plan used in this later development is illustrated by Fig. 1114, from Bemberg's English Patent No. 224,864. The coagulating solution enters the coagulating chamber at *s*, under pressure, and leaves through both *r* and *d*, as indicated by the arrows. The spinneret is indicated at *b* and the thread

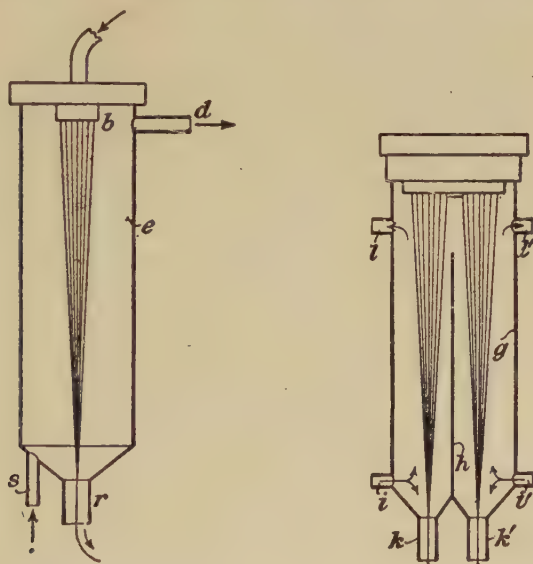


FIG. 1114. Stretch-spinning Device. (Bemberg.)

leaves the chamber at *r*, along with a part of the coagulating bath. By properly regulating the flow of the coagulating bath at *s*, *r*, and *d*, a gentle stretching of the incompletely coagulated thread occurs. This permits the use of spinnerets containing larger holes than would normally be the case, for fine denier filaments, while the completely coagulated thread may be even finer than with the smaller spinneret holes.

Figure 113 illustrates a centrifugal-pot spinning machine utilizing the above stretch spinning principle. In this figure the stretch spinning chambers are designated by *A-A*. The brief specifications for this machine are as follows:

Each machine has 60 spinning sets, 30 on each side. Distance between centers, 10 inches. The supply pipes for the spinning mass and water are made of iron, supplied without spinning funnels, spinning nozzles, hose and valves. Overflow-glass bar below the spinning funnels, wooden trough to collect the water from the spinning funnels, earthenware channels with acid drip pipe. Wooden channel with lead lining to collect the spent acid. Fluted-glass overflow rolls and change wheels to regulate their speed from 35 to 50 meters per minute.

Acid-proof centrifugal spinning motors with patented elastic bearings, arranged to be taken out through the spinning-pot casings from top. Separate switch for each motor, exclusive of frequency converter. Spinning pots made of aluminum with ebonite lining (may also be made of steel or phosphor bronze). Glass funnels arranged on top of the spinning pots, change motion for funnels by eccentrics. Spinning-pot casings made of wood and totally lined with lead, exclusive of spinning mass pump. Drive of glass rolls and eccentric motion by separate electric motors, each of 0.5 H.P. Approximate weight: net 16,060 pounds.

After-treatment and Finishing of the Spun Thread.—When the cake, bobbin or reel, as the case may be, contains the desired amount of Rayon it is removed from the machine and treated for the removal of the copper present in the thread. The extent of the treatment necessary to remove this copper varies somewhat according to whether an acid or alkaline spinning bath was used. Where the final coagulation occurs on the bobbin, in an acid bath, wherein a portion of the bobbin is immersed in the spinning bath, a great deal of the copper is removed by the coagulating bath. However, in

the alkaline spinning process this is not the case. But in every case some copper remains in the thread and this must be removed.

In some cases the bobbins are placed upon racks, those coming from the spinning room going on the bottom row of the rack and moving upward as the copper is removed. A dilute sulphuric or hydrochloric acid solution, from a distributing pipe at the top, drips down over the bobbins and thence to a drain. The copper-free bobbins are removed from the top of the rack. The copper-free bobbins are transferred to another rack, similar to that used for the acid treatment, where they are rinsed free of all acid by means of soft water. The same bottom to top movement of the bobbins, described in the acid treatment, is again utilized here.

Where the alkaline precipitation process is used, the Rayon is often wound into hanks (Fig. 115), and these hanks are treated with the acid solution for the removal of copper, on the same type of machine described for washing and treating Viscose.

After the bobbins have been washed they are placed on trucks and wheeled into a dryer. This dryer is very much like the dryer used in the bobbin method Viscose process and is fitted with practically the same equipment. After drying the bobbins are cooled and then treated in a humidifying room to put back a certain percentage of moisture so as to facilitate winding.

The several filaments must now be combined into a uniform thread by twisting, but where the large and unwieldy glass bobbin is used, this is placed on a spooling machine and the Rayon rewound upon a spool. The spools are then taken to the twisting machines and the necessary twist imparted. The twisting machine differs very little either in type or operation from the one used in this same operation in the Viscose process. In one or two instances attempts have been made to

twist directly from the glass bobbin without a spooling process, and while this is possible, it has been found faster and cheaper to use the spooling step.

The spools are taken from the twisting machines and reeled into skeins. The skeins are then bleached, soaped, and dried as described in the production of Viscose Rayon. The skeins

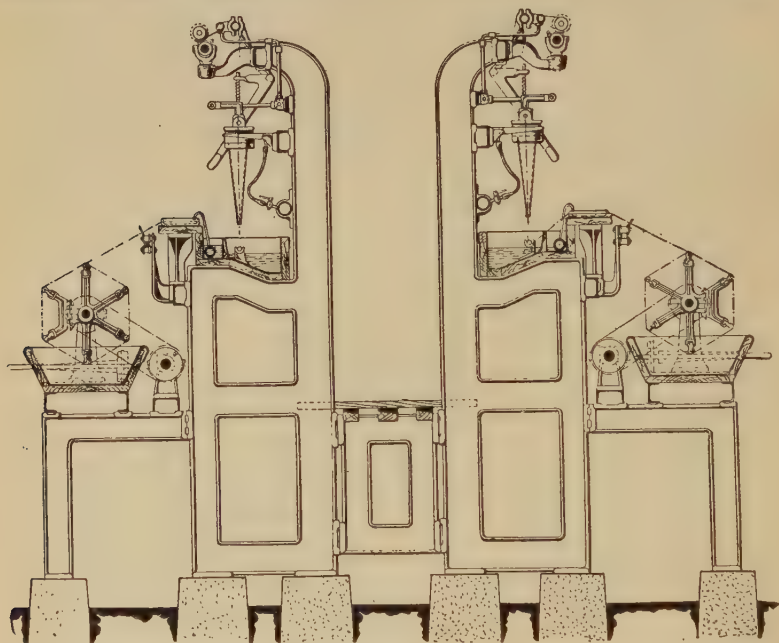


FIG. 115. Reel Stretch Spinning Machine. (Courtesy of C. G. Haubold, A. G. Chemnitz, Germany.)

are laced and tied, removed from the reel fly and taken to the sorting room. The sorting of the Rayon into grades is as important as it is in the Viscose process and equal care must be exercised to see that this is properly done. Following the sorting and grading, the skeins are bundled, packed and shipped. Bundles and cases are of the same size as employed in the Viscose process. Rayon made by the cupra-ammonium

process is quite white in color when cotton linters are used as basic raw material. It is, however, often bleached.

In the case of stretch spinning, if the thread is wound on bobbins it is treated as described in the previous paragraphs; if produced by the pot stretch spinning method the subsequent procedure, from the cake on, is practically the same as for the Viscose process.

Recovery of Chemicals.—Economical production of Rayon by the cupra-ammonium process requires the recovery of copper and ammonia. While the entire amount cannot be recovered a large portion is obtained, depending on the methods employed. The reader is referred to Chapter XV on Recovery of Chemicals and Solvents for further discussion of the subject.

CHAPTER XIII

THE NITRO * OR CHARDONNET PROCESS

History.—The so-called nitro-cellulose process receives its name from the fact that cellulose nitrate, commonly called nitro-cellulose, is the basic material, used in the spinning of the Rayon. This is the oldest Rayon or artificial silk process known and was first commercially and successfully developed by Count Hilaire de Chardonnet. As the oldest Rayon process, it is to be expected that it may be better understood than any of the other processes, but even so, much yet remains to be learned regarding cellulose and cellulose nitrate. The nitro silk process is closely related to the celluloid and explosives industries, both of which also use cellulose nitrate in enormous quantities. While cellulose nitrate was discovered in 1845, by Schoenbein, it was not until much later that any practical use was made of the product.

The first English patent covering the use of cellulose nitrate in Rayon manufacture was granted by Georges Audemars, of Lausanne, in 1855. In 1883 Swan was granted a patent for squeezing the nitrate through small holes into a coagulating bath, thus forming continuous uniform filaments. In 1884 Count de Chardonnet obtained French Patent No. 165,349 covering his method of forcing the cellulose nitrate solution through small holes into heated air, which evaporates the solvent and forms continuous filaments which can be collected on a bobbin, twisted, wound into skeins, etc.

* The term nitro-cellulose, while in common use, is not correct in that the material used in the manufacture of "nitro" Rayon is a true ester of cellulose, cellulose nitrate, and not a nitro-cellulose.

The thread thus produced by Audemars, Swan and Chardonnet therefore consisted of cellulose nitrate and was very inflammable, in fact even explosive, dangerous, and useless for textile purposes. So dangerous that the French Government passed a law prohibiting its use in textiles. It was then that Chardonnet was compelled to use the Swan denitration process, which was first patented in England by Weston in 1882 (Patent No. 4458), in which the nitrate group in the thread is removed with the regeneration of a hydrated cellulose thread that is no longer either highly inflammable or explosive.

Chardonnet's first plant was located at Besançon and in 1891 had a production of about 30,000 pounds. Another plant was located in Switzerland. The third plant was built by Wardle and Davenport, Ltd., of Leek, at Tubize. The next plant was located at Brandon, England. The present large Tubize plant at Hopewell, Va., is a development of the Belgium Tubize Company.

The raw materials for the manufacture of nitro Rayon are as follows:

(a) Cotton linters is the principal source of cellulose although cotton waste or even raw cotton can be, but seldom are, used. Wood pulp, high in alpha cellulose and in the form of crepe tissue paper can also be nitrated successfully, but it has probably never been used in Rayon manufacture.

(b) Nitric acid.

(c) Sulphuric acid.

(d) Ether (ethyl or sulphuric ether).

(e) Alcohol (ethyl or grain alcohol).

(f) Sodium Hydrosulphide.

The above are the principal materials used in the preparation of the cellulose and the making of the Chardonnet Rayon thread, not taking into consideration other chemicals employed in the finishing processes of the thread, nor the very important element, water, the quality and purity of which cannot

be any different than the water called for in the manufacture of Viscose Rayon. Chapter IX on Rayon Engineering Problems discusses water and the problems of its purification, and should be considered in conjunction with the study of this chapter.

STEPS IN THE NITRO PROCESS

The principal steps in the making of Cellulose Nitrate Rayon are the following:

- (A) The purification of the raw material—cotton.
- (B) The nitration of the cotton.
- (C) The dissolution of the cellulose nitrate for spinning.
- (D) Spinning the solution.
- (E) After-treatment of the spun thread.
- (F) Denitration.
- (G) Finishing.
- (H) Solvent Recovery.

A. THE PURIFICATION OF THE RAW MATERIAL: The cotton linters used in the nitro process of Rayon manufacture are of the same type and grade used in the cupra-ammonium process and the reader is referred to Chapter XII for the discussion of the impurities present and their removal.

1. After the usual kier boiling process the linters are rinsed and

2. Bleached with hypochlorite solution in the manner described in Chapter XII. Cellulose nitrate from bleached cellulose is more soluble in the ether-alcohol solvent used than that from unbleached cellulose.

B. NITRATION OF THE COTTON: The cellulose is treated with the nitric acid to give the required cellulose nitrate, according to the following steps:

3. The purified and still wet cellulose is treated or "nitrated" with a mixture of nitric and sulphuric acids.

4. Spent acid is separated from the cellulose nitrate.

5. Washed, neutralized with sodium carbonate and re-washed.
6. Broken up or shredded.
7. Boiled to remove last traces of acid, and decompose sulphates present.
8. Hydroextracted.
9. Tested for nitrogen content, solubility and viscosity.

3. *Acid Mixture*.—The transformation of the purified cotton into cellulose nitrate is accomplished by immersing it in a mixture of nitric and sulphuric acids.

Depending upon the conditions under which the nitration of the cellulose occurs, products containing widely varying amounts of nitrogen are obtained. However, it is very possible that only three nitrates of cellulose can be prepared by the usual processes in use. These three products are the mono-, di-, and tri-nitrates of cellulose. Table 89 gives the formula and nitrogen content of each. According to this table a true cellulose nitrate cannot contain more than 14.2 per cent of nitrogen and this is very probably true. However, many other nitrates of cellulose are mentioned in the literature. It is very probably that these consist of mixtures of one or more of the nitrates with unnitrated cellulose, mixtures of two or three nitrates, or mixtures of the nitrates with nitrated cellulose decomposition products, some of which contain more than 14.2 per cent of nitrogen.

TABLE 89.

	Formula	Nitrogen Content Per Cent
Cellulose mononitrate.....	$C_6H_9O_4NO_3$	6.8
Cellulose dinitrate.....	$C_6H_8O_3(NO_3)_2$	11.1
Cellulose trinitrate.....	$C_6H_7O_2(NO_3)_3$	14.2

In the usual nitration process for the preparation of cellulose nitrate for use in the manufacture of Rayon, it is quite probable that a mixture of the nitrates is always obtained. The properties of this nitrate mixture varies considerably with its nitrogen content, as well as with the character and previous history of the original cellulose, the many variables possible in the nitration process, etc. These factors largely control the solubility of the cellulose nitrate, the viscosity of the resulting solution, its stability, etc.

The higher nitrates of cellulose, that is, those containing more than about 12.5 per cent of nitrogen are largely used as explosives, either alone or mixed with other materials, while the nitrates containing slightly less nitrogen, say 10.5 to 12.5 per cent, are used in Rayon manufacture. These lower nitrates are more soluble in mixtures of alcohol and ether than those containing more than 12.5 per cent of nitrogen. The solution of cellulose nitrate in this ether-alcohol mixture is called collodion and is used for other purposes than the production of Rayon, for example, as a liquid court-plaster and in the manufacture of celluloid, smokeless powder, etc.

The Nitration Process.—The preparation of the cellulose nitrate is a very important step in the production of the Rayon, in that many apparently unimportant factors greatly influence the various properties of the resulting Rayon. As it is absolutely necessary to produce just as uniform a Rayon as possible, it is absolutely essential that all of these factors be under very close control during the nitration. Some of the important factors are the relative proportions of nitric and sulphuric acids and water in the nitrating bath, the temperature and time of nitration, ratio of cellulose to bath, previous history of the cotton such as the kier boiling and bleaching operations, etc.

Numerous combinations of the above factors can be, and are, used in the production of cellulose nitrates. The various percentages of nitric and sulphuric acids used, as well as the

amount of water present in the mixture, the temperature and time, all appear to vary widely in different plants. Wheeler gives the following table as typical of combinations of conditions giving a cellulose nitrate suitable for use in the manufacture of Rayon.

TABLE 90.

NITRATING CONDITIONS SUITABLE FOR THE PRODUCTION OF NITRO RAYON *

Time of Nitration	Temperature of Nitration	PER CENT COMPOSITION OF MIXED ACID		
		HNO ₃	H ₂ SO ₄	H ₂ O
1 to 1½ hours.....	104° F.	37.5	48.0	15.0
10 minutes.....	122° F.	31.5	53.8	14.7
20 to 30 minutes.....	86° F.	17.0	66.0	17.0

Mass relationship: 1 part purified of cotton to 25-60 parts of acid mixture.

* E. Wheeler, "The Manufacture of Artificial Silk," p. 62.

Three mechanical processes of nitration are in use but only two have found any extended use in America.

(a) *The Pot Process*.—The original process consisted of treating the purified and thoroughly dried cellulose in the acid mixture contained in porcelain or clay pots, or troughs. While cast-iron nitrating pots are in common use for the production of explosives, the resulting cellulose nitrate is usually yellowish and for this reason iron is seldom used in nitration for Rayon production. The cotton is slowly added to the acid in the pot and allowed to remain for the desired length of time at the predetermined temperature. The cellulose nitrate is then either centrifuged, as described below, to remove as much free acid as possible; or it is first washed in a large volume of water and then centrifuged. The former procedure is probably in most common use.

(b) *The Centrifugal Process*.—This is a later development wherein the cotton is both nitrated, centrifuged, and washed in a specially constructed centrifuge, lined with an acid-resisting material such as stoneware. The centrifuge is equipped with suitable valves to prevent the acid leaving the body of the machine during the actual nitration period. The cotton is carefully placed in the bowl, which is revolved slowly and the acid mixture admitted. After a suitable period of time the acid solution is released, the centrifuge speeded up so as to remove as much acid as possible, and then the cellulose nitrate washed with a heavy spray of water. See Fig. 112.

(c) *The Thompson Displacement Process*.—This method has never come into very wide usage outside of England. The nitration proceeds in the usual manner, but in shallow earthen ware pans, with frequent stirring. When the reaction is complete, the acid in the pan is displaced by water, after which the procedure is the same as in the pot process.

4. *Acid Removal*.—When the cellulose is nitrated by either the pot or displacement methods it is necessary to remove the excess of acid from the fibres at the end of the nitration period. This is usually done by centrifuging the cellulose nitrate. When the centrifugal nitrating process is used, the acid is removed in the same machine in which nitration occurs, by simply drawing off the acid solution and speeding up the centrifuge.

5. *Washing of Nitrated Cellulose*.—After the removal of as much acid as possible by centrifuging, the cellulose nitrate is washed in a large volume of cold water and finally in hot water until all free acid is removed from the fibres. This washing is frequently conducted in the centrifuges. It is common practice to neutralize any traces of free acid remaining in the cellulose nitrate, after the preliminary washing, with sodium carbonate solution. A thorough water wash is then given to remove all alkali and salts.

6. *Shredding*.—The nitrated cellulose then passes to a disintegrating machine where, by means of a revolving bronze cutter, the material is reduced to fibers about .04 inch long. Washing is also going on during this operation, as the shredding is carried out under water.

7. *Boiling*.—After the shredding operation the cellulose nitrate pulp is boiled with water to remove the last traces of free acid, certain more or less unstable nitrated decomposition products of cellulose, and any cellulose sulphate remaining with the nitrate. The cellulose decomposition products are formed during the nitrating process, due to the destructive (hydrolytic) action of the acid nitrating solution on the cellulose. They are considerably less stable than the cellulose nitrate. The cellulose sulphate is also formed during the nitrating process, due to the action of the sulphuric acid present on the cellulose. As the cellulose sulphate is considerably more soluble in hot water than the nitrate, it is also largely removed during this boiling operation. As a result of the boiling process, the cellulose nitrate is stabilized to a considerable extent. After the boiling, the cellulose nitrate is well rinsed to remove the last traces of boiling liquor.

8. *Hydro-extracting*.—The water in the shredded nitrated cellulose is now eliminated by means of hydro-extractors or hydraulic presses until the moisture content does not exceed 25 to 35 per cent. It is seldom, if ever, dried.

9. *Cellulose Nitrate Tested*.—The cellulose nitrate in this final form is tested for:

- (a) Solubility.
- (b) Viscosity.
- (c) Stability.
- (d) Nitrogen content.

During the nitration process the progress of the reaction is followed by observing the fibers under the microscope with

polarized light. The reaction appears to take place on the surface of the fibers first and is not complete until the fibers appear to be uniform throughout, under crossed Nicols.

If the quality of the cellulose nitrate is found to be satisfactory, by the above tests, it is used for the preparation of the spinning solution; otherwise it is rejected and used for some other purpose.

The nitrating department must be well ventilated in order to remove the acid fumes, which are dangerous to health. This is accomplished by hoods and ventilators. Since the acid loss by fumes runs as high as 25 pounds per 100 pounds of cellulose nitrate, these fumes are caught in towers, concentrated and reused.

C. PREPARING THE SPINNING SOLUTION:

10. *Dissolving the cellulose nitrate in a mixture of ether and alcohol.*

11. *Storage until needed and to remove air bubbles.*

12. *Filtration.*

13. *Dissolving the Cellulose Nitrate.*—In preparing the cellulose nitrate solution or collodion, the first step is to dissolve the nitrate in a mixture of alcohol and ether. The relative proportions of alcohol and ether, as well as that of mixed solvent solution to the cellulose nitrate, will depend upon whether the wet or dry spinning process is to be used and the strength of cellulose solution desired. Either ethyl (grain) or methyl (wood) alcohol can be used in the spinning solution, but the ether (ethyl or sulphuric) is of the same variety used as an anaesthetic in hospitals.

The cellulose nitrate content of the spinning solution varies with the method of spinning to be used, *i.e.*, wet or dry, as will be explained later. When the wet-spinning process is used, the spinning solution usually contains only about 10

per cent of cellulose nitrate, but for dry spinning a 20 to 25 per cent solution of the nitrate is used. The constitution of the solvent mixture also varies with the process of spinning. In wet spinning very little ether is present and a proportionately large amount of alcohol is used. In dry spinning the solvent mixture may be approximately 60 per cent ether and 40 per cent alcohol. The dissolution of the cellulose nitrate in the solvent solution is accomplished by "tumbling" the nitrate and solvent solution ("mélange") in a closed mixer of the egg type, without baffles or agitators, for 24 hours.

14. *Storage and Deaeration*.—This cellulose nitrate-ether-alcohol solution is called collodion and is usually a very heavy or viscous solution. It runs from the mixer or "egg" into large storage tanks, where it is allowed to remain for some time so that the air bubbles may rise to the surface. The collodion is withdrawn from these tanks as needed and is quite stable.

15. *Filtration*.—The collodion is withdrawn from the storage tanks as needed, directly into very heavy hydraulic presses. These presses force the paste through the cotton and silk filtering medium directly into the main pipe line feeding the spinning machines.

2. SPINNING THE SOLUTION: Two methods are used for spinning the cellulose nitrate or collodion solution:

14. The Dry Spinning Method.

14A. The Wet Spinning Method (not used in America).

14. *Dry Spinning*.—The present practice favors the dry-spinning process, wherein the collodion solution is forced through fine holes into air, instead of into a coagulating bath, as in the case of Viscose and cupra-ammonium Rayons. On the early spinning machines long rows of glass fine capillary tubes were arranged along the collodion supply pipe, the indi-

vidual filaments of a suitable number of capillary tubes being collected and wound together, untwisted, on the bobbin to give the desired denier of thread. Today a somewhat different arrangement of the capillary tubes is made, but each filament is spun independently from a separate glass capillary.

The spinning of course takes place in a closed chamber, in order to avoid loss of solvents, and for the same reason the bobbin, on the outside of the chamber, revolves in water at very near the freezing point.

In order to use the dry-spinning process the spinning solution must contain a relatively high percentage of cellulose nitrate and the solvent must contain considerable ether, which is very volatile. Under these conditions the filaments harden immediately upon striking the air and have no further tendency to cohere.

The solvent vapors from the dry-spinning chamber are conveyed to an absorption tower, where they are absorbed in suitable material. While the dry-spinning process offers certain advantages, in that the thread is formed in a single, very simple operation, in the dry state, from a concentrated spinning solution, it also presents some disadvantages as regards solvent recovery.

14A. *Wet Spinning.* The wet spinning process, which in general principle is similar to the spinning of Viscose silk, also offers certain advantages in that the spinning solution is more dilute and, therefore, of lower viscosity. This means that lower filtering and spinning pressures can be used, with the result that considerably lighter construction is possible in the mechanical equipment. However, the wet spinning process for nitro-Rayon has never been successful in America.

In the wet spinning process, the spinning solution is forced through the spinneret into water, in which the alcohol-ether solvent mixture is soluble. The filaments may be stretched

while still in the plastic state, in order to give a finer filament or yarn, and is gathered and wound as usual in the wet spinning process, either on the bobbins of machines similar to those described in the chapter on the Viscose Process.

On account of the volatility of the solvents used, the spinning baths are covered to prevent loss of the solvents by evaporation. The spinning bath is, of course, treated for the recovery of the solvents by distillation. It is very probable that the wet process of spinning nitro-Rayon is no longer in use.

Chardonnet first used the wet-spinning process with water as the coagulating bath, but shortly abandoned this for the dry-spinning process, especially after he had discovered the greater solubility and viscosity of the hydrated cellulose nitrates.

15. The handling of the nitro Rayon after it reaches the bobbin stage is exactly the same as in the manufacture of Viscose Rayon. It is spooled, twisted, and skeined on exactly the same type of machines as those described in connection with the manufacture of Viscose.

E. DENITRATION:

16. Since the cellulose nitrate thus produced is inflammable, explosive and useless, it is necessary to remove the nitrate group, which converts the thread to a regenerated cellulose. Hence the process of regenerating the cellulose is known as denitration.

Numerous reagents have been suggested for use in denitrating the cellulose nitrate fibres but apparently none of these have been able to displace sodium hydrosulphide for this purpose. This always contains some sodium sulphide as an impurity, however, and this is very desirable or necessary. This hydrosulphide is cheap and has little effect upon the

thread, if the treatment is properly controlled and not carried too far. The Rayon is denitrated in the form of skeins, and these are treated in vats by hand. About three hours are usually necessary to complete the treatment. While sufficient nitrate remains in the fiber to give the nitrate test, whereby the nitro-Rayon may be identified, it is not sufficient to affect its inflammability.

Denitration was compelled, in the early days of Char-donnet's work by the French authorities and later by the merchants who refused to handle so inflammable a product. Hence in 1893 the cellulose nitrate Rayon became, through denitration, a regenerated cellulose fiber having the same combustibility as cotton, flax and hemp.

Denitration has the very undesirable effect of reducing both the tensile strength and elasticity of the Rayon, but no way has ever been found to overcome this difficulty. It also reduces the weight of the thread considerably, due to the removal of the nitrate groups, and it is claimed that fabrics composed of the regenerated cellulose nitro Rayon do not have as good draping qualities, nor as full a handle, as those of the original undenitrated cellulose nitro Rayon.

G. FINISHING:

17. *Washing, Bleaching and Drying.*—After denitration the hanks are washed and, if discolored from the sulphide treatment, are treated with a hot but very dilute nitric acid bath. After washing free of acid, they are bleached, usually with sodium hypochlorite, soured, and washed until free of all acid and bleaching chemicals. They are then centrifuged and carefully dried at a low temperature. These operations are usually conducted in the same manner as on Viscose Rayon.

18. The skeins are finally inspected, graded, sorted, packed, stored and shipped.

(a) Stability of the spinning solution.

Advantages of the nitro or Chardonnet process:

(b) Comparative simplicity of apparatus.

(c) Strength of the original thread as spun, before denitration, which permits considerable handling without injury to the filaments.

(d) The time factor so important in the aging of the Viscose alkali-cellulose and cellulose-xanthate, is of little importance with Chardonnet Rayon.

(e) The dry-spinning operation is less delicate than wet spinning.

(f) Chardonnet Rayon consequently gives a higher yield of first-grade Rayon and is better suited for the production of the finer denier yarns than certain other processes.

Disadvantages of the nitro or Chardonnet process:

(a) Cost of nitration and denitration.

(b) Cost of solvents, which can only be partly recovered.

(c) Inflammability of cellulose nitrate prior to denitration.

H. SOLVENT AND ACID RECOVERY:

The great disadvantage of the process is the high total cost of the Rayon. Practically all of the chemicals used, both in the treatment of the cellulose (nitric acid) and in the preparation of the spinning solution (ether and alcohol) are considerably higher in price than those used in the Viscose process. There is always a large loss of these expensive materials, due to the expense and practical impossibility of 100 per cent recovery. The successful operation of the nitro process very largely depends upon the efficiency of this recovery.

It is not the purpose to discuss the recovery processes at this point as they will be treated in Chapter XV. The acid recovery is treated in works covering the subject of manufacturing explosives.

Labor.—Highly skilled labor is required not only in the chemical divisions but also in the textile division. In fact, neat, careful work is required in both divisions. Men are usually preferred in the chemical section and women in the textile, where their greater deftness and fineness of touch comes into play.

Present Practice.—While many changes and possible improvements in the original processes of Chardonnet and Lehner have been suggested, almost none of them have ever come into any wide commercial usage, so that even today the processes still in use are very similar to those developed by the pioneers in the industry. While nitro-Rayon appears to offer some definite advantages for certain purposes, the fact that its production does not keep pace with that of its later competitors is significant. It has recently been stated that it is no longer manufactured in France, the country of its origin.

CHAPTER XIV

THE ACETATE PROCESS

History.—Cellulose acetate was first prepared by Schutzenberger, in 1865, by heating cellulose and acetic anhydride in a closed tube. Franchimont in 1879 discovered the so-called catalytic action of sulphuric acid and certain other compounds in this esterification process. These catalysts are still almost universally used. Cross and Bevan developed the first feasible process for the preparation of cellulose acetate in 1894, which they covered in British Patent No. 9,676.

Count Henckle von Donnersmark acquired the German rights to the Cross and Bevan patent and later sole rights under the Mork, Walker and Little patents of later date. He founded the Fürst Guido Donnersmarcksche Kunstseide and Acetatwerke and erected a plant at Sydowsaue, near Stettin, in 1898. This company conducted many experiments upon the acetylation of cellulose and the spinning of acetate Rayon, and was granted many patents covering acetylation processes, all of which apply only to the primary or chloroform soluble acetates.

This plant is sometimes credited, particularly in Germany, with producing the first acetate Rayon. However, no real acetate Rayon was ever produced, the nearest approach being a stiff and wiry monofilament thread resembling the artificial horsehair of today, and this only upon an experimental scale.

The early American pioneers in cellulose acetate and acetate Rayon were H. S. Mork, A. D. Little and W. H. Walker. These gentlemen secured United States Patent No. 709,922

in 1902, and many subsequent patents. Through their efforts the Lustron Company was founded in Boston, Mass., and this company was probably the pioneer in the production of acetate Rayon on a commercial scale. The company was never very successful, either technically or financially, and discontinued production in 1927. Probably one of the principal difficulties with their process was with the type of cellulose acetate used. The Lustron process utilized an acetate closely approximating cellulose triacetate, of the type designated as primary cellulose acetate. The primary acetates are soluble only in chloroform and similar expensive and toxic solvents, and possess quite different properties from the acetone-soluble (secondary) acetates, which have thus far proven to be the only products suitable for the production of acetate Rayon.

The most important development in cellulose acetate in the period immediately following the patent of Cross and Bevan was that due to G. W. Miles. He discovered that by a suitable treatment the chloroform-soluble cellulose acetate obtained by the direct acetylation of cellulose (primary acetate), could be converted into a type soluble in acetone and certain other cheap solvents (secondary acetate). This step has been designated by various investigators as a hydration, hydrolysis, ripening or saponification. It appears that it may be a depolymerization, disaggregation, or peptization process. This process was covered by United States Patent No. 838,350 of 1906 and German Patent No. 252,706, the latter to the Bayer Company.

The value of this process lies in the solubility of the Miles acetate in comparatively cheap and volatile solvents, such as acetone, from which it is easier and cheaper to produce filaments and films than with the primary acetate from a chloroform solution. Furthermore, these secondary or acetone-soluble acetates usually give better films and filaments than the chloroform-soluble acetates.

Many scientists were connected with the minor developments of the next few years but nothing of importance occurred until the Dreyfus brothers entered this field. Drs. Camille and Henry Dreyfus started working upon cellulose acetate in Basle, Switzerland, in 1910 and produced some acetate filament upon an experimental scale before 1913.

During the World War these scientists were called to England to supervise the production of cellulose acetate for use in the preparation of aeroplane dopes. At the close of the War the Dreyfus brothers formed the British Cellulose and Chemical Manufacturing Company, which understood the commercial development of acetate yarn. This was the parent company of the present British Celanese, Ltd., and associated companies. The first experimental work was again conducted in Basle, but commercial production was established in the company's plant at Spondon, England, in 1918. Thus was developed "Celanese," the first really successful, either technically or financially, acetate yarn.

Considerable difficulty was experienced at the start so that early in 1921, after attaining a production of as much as 5000 pounds per day, the output was reduced to about 1000 pounds daily. During the latter part of 1921 the production was again increased to about 2000 pounds daily. Along with these early difficulties in production came the accumulated scientific knowledge and experience which resulted in the Celanese of today, which has frequently been stated to be superior to all other artificial fibres for many purposes. Production has steadily increased up to date, the British production being about 10,000,000 pounds in 1928.

Celanese was first produced in America about 1918 and large-scale operations were started in 1922 at Amcelle, near Cumberland, Md. The 1928 production was 5,000,000 pounds. A Canadian plant was built at Drummondville, Quebec, in 1927. This plant has a capacity of 1,500,000

pounds annually. The Soie Artificielle de Tubize of Brussels, Belgium, and the Société Française de Tubize of Lyons, France, also produce acetate yarn under the Dreyfus patents. It is interesting and significant to note that of the 25,000,000 Belgian francs profit of the Belgian Tubize company in 1928, which manufactures acetate, nitro and Viscose Rayons, 20,000,000 francs were from the production of acetate only. It has been stated that the Belgian Tubize company is producing about 2,500,000 pounds, and the French company about 2,000,000 pounds, of acetate yarn annually.

Some time after the War the Société pour la Fabrication de la Soie "Rhodiaseta" was founded by the Comptoir des Textiles Artificiels and the Société Chimiques des Usines du Rhône, the latter company having had some ten years previous experience in the production of cellulose acetate. This company produces the "Rhodiaseta" brand yarns. It is associated with the Deutsche Acetat Kunstseide Rhodiaseta A.G., which is now producing at Freiberg, Germany, by the acetate process.

The DuPont Rayon Company of New York has also completed negotiations with the Rhodiaseta company and has built a plant at Waynesboro, Va., to produce acetate Rayon under the Acele brand. They will probably start production in November, 1929.

Courtaulds, Ltd., of London, have been experimenting upon the production of acetate Rayon for some time and produced some acetate yarn early in 1928; however, production has been discontinued several times. Their American branch, the Viscose Company, has a plant at Meadville, Pennsylvania, and will produce acetate Rayon under the same brand. It is scheduled to start production late in 1929.

The American Chatillon Corporation of New York, an associate of La Soie de Chatillon of Italy, has built an acetate

and Viscose Rayon plant at Rome, Georgia. They started production in middle of 1929. While the parent Italian company has had considerable experience in the Viscose field, it also produces acetate Rayon abroad upon a commercial scale, having just completed a plant of a capacity of 7000 pounds daily. Both the Italian and the American Chatillon operate under the Ruth-Aldo acetate silk patents.

The Aceta G.m.b.H. of Berlin-Lichtenberg, Germany, has produced some acetate yarn, but operations have not been continuous. They probably first entered commercial production in 1928.

La Setyl Italiana of Milan, Italy, has been stated to be producing about 150,000 pounds of Setyl brand acetate yarn annually. In addition to the above, some twenty or more other companies are either producing, or are planning to produce, acetate yarn in the near future.

While the products of the Celanese and Rhodiaseta companies are constant and uniform, they are not by any means identical, nor will they be identical with those of the newer plants. As yet it remains to be seen just how uniform these newer products will be. Just as all other Rayons vary from plant to plant and, unfortunately, sometimes from the same plant, so we may expect the product of each individual acetate Rayon plant to have somewhat different properties than that of any other plant and, therefore, to dye just a little differently. And, speaking of dyeing, it has been stated many times that the present success of, and interest in, acetate yarn is largely due to the fact that the former difficulties in dyeing and printing it have largely been overcome.

Just as in the case of the development of acetate yarn itself, we are almost entirely indebted to the Dreyfus brothers for the development of the now really successful dyeing and printing processes for acetate yarn. While there is a certain demand for white effects in dyed goods, this demand is

strictly limited, and it is only through the constant and diligent efforts on the part of these scientists that we now have the really satisfactory dyeing and printing methods which mean the complete success and large-scale production of acetate Rayon.

Chemistry of Acetate Rayon.—Before going further into the production of acetate Rayon it is desirable to compare this synthetic fibre with the Nitro, Viscose and Cupra-ammonium Rayons just described in Chapters XI, XII, and XIII. In the first place the Rayons previously discussed were, in the marketable or finished condition, regenerated cellulose products. On the other hand, acetate Rayon is a true synthetic fiber, in that the fiber itself, in the finished or marketable condition, consists of the compound cellulose acetate, prepared from cellulose and acetic acid. It therefore differs from the older Rayon products, in that it is a truly synthetic fiber, cellulose acetate an ester of cellulose, and not a regenerated cellulose Rayon.

While each process of Rayon production differs in many respects from that of all others, the process used in the manufacture of nitro Rayon most nearly resembles that of acetate Rayon. In the case of nitro, the material from which the fiber is spun is cellulose nitrate, while with acetate Rayon it is cellulose acetate. Both the nitrate and acetate are esters of cellulose and are dissolved in suitable volatile organic solvents from which the threads are dry spun, but by quite different methods. The greatest difference in the production of the two fibers, however, is in the treatment after spinning. While it is necessary to put the nitro Rayon threads through a long denitrating process after spinning, which leaves a regenerated cellulose fibre, no such treatment is necessary in the case of acetate Rayon and the spun fiber is ready for use without any further chemical treatment. It remains as it was

spun, a cellulose ester, cellulose acetate, a synthetic fiber, in the broad meaning of the term.

Briefly, the process of manufacture of acetate Rayon may be outlined as follows: Under suitable conditions cellulose combines with acetic acid to form the cellulose ester, cellulose acetate, which in certain, but certainly not all, respects resembles cellulose nitrate, which was discussed in connection with nitro Rayon. Cellulose acetate is soluble in certain organic solvents, some of which have a very high rate of evaporation, so that when the cellulose-acetate solution is forced through the spinneret into warm air, a thread or filament is formed due to the evaporation of the solvent. This is known as "dry spinning." No subsequent chemical treatment of the thread is necessary, unless it is to be bleached, and this is not usually necessary.

The production of the thread may, therefore, be divided into two principal processes:

1. The preparation of the spinning solution.
2. The spinning operation.
 - (A) Purification of the linters.
 - (B) The formation of the cellulose acetate, known as the esterification process.
 - (C) Conversion of the chloroform-soluble (primary) cellulose acetate into the acetone-soluble (secondary) acetate.
 - (D) Precipitation, purification and drying.
 - (E) Solution of the cellulose acetate to give the desired spinning solution.

These steps may be briefly elaborated as follows:

- A. The linters are purified by kier boiling.
- B. The highly purified cotton linters are treated with acetic anhydride in the presence of a so-called catalyst, usually sulphuric acid, and generally but not always a solvent for the resulting cellulose acetate, such as acetic acid.

C. This solution is then usually treated in some manner so as to convert the chloroform-soluble primary * cellulose acetate into the acetone-soluble secondary cellulose acetate.

D. When the desired solubility and other characteristics have been obtained, the cellulose acetate is precipitated by the addition of water and washed until all free acids are removed. It is then carefully dried. It is usually in the form of white flakes.

E. The final step is the solution of the dried cellulose acetate in a suitable solvent, usually containing acetone, in the proportion necessary to give the resulting spinning solution the desired characteristics. This solution is finally filtered and deaerated, as in the manufacture of all other types of Rayon, when it is ready for spinning.

A. The purification process of linters for the manufacture of cellulose acetate is exactly the same as in the manufacture of the other types of Rayon. They should be very clean, well opened out, low in ash, grease and oxycellulose. For further details as to purification, see Cupra-ammonium Rayon. In some cases this cellulose is given either a mercerization or an acid treatment preliminary to the actual esterification process, so as to render it more reactive in the latter process. The moisture content of the cellulose for acetylation is carefully adjusted, according to the formula to be used. This is very necessary in order to obtain a uniform product.

B. The simplest chemical formula for cellulose is $C_6H_{10}O_5$, in which x is an unknown but fairly large number. To the chemist this formula indicates that the cellulose molecule, or smallest unit, consists of a number of these $C_6H_{10}O_5$ groups. As yet we do not know all that could be desired regarding the structure of cellulose, but we do know that each of these $C_6H_{10}O_5$ groups contains three

*Cellulose acetates soluble in chloroform and similar solvents, but insoluble in acetone, are usually designated as primary cellulose acetates. Those soluble in acetone but insoluble in chloroform are called secondary acetates.

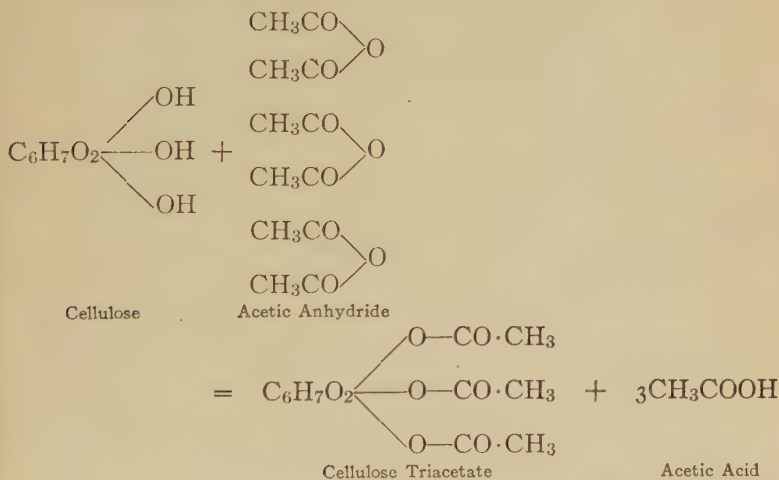
hydroxyl (OH) radicals, and that each of these hydroxyl radicals will combine with an acid group, under suitable conditions, to form an ester of cellulose. In the case of cellulose acetate, this is technically known as cellulose triacetate.

Other cellulose acetates are possible, however, just as in the case of the cellulose nitrates, so that theoretically, at least, we have cellulose monoacetate and cellulose diacetate, besides the triacetate. In the acetylation* of cellulose, for some reason, only the triacetate is formed and if sufficient acid groups are not present to join with all of the hydroxyl groups in the cellulose, under the prevailing conditions of acetylation, a mixture of cellulose triacetate and uncombined cellulose results.

According to Heuser, "Cellulose Chemistry," this reaction is expressed by the equation:



or as a structural equation:



*This step is commonly spoken of as acetylation but as it is really a true esterification process, it appears that it is more correctly designated as acetylation, just as the formation of cellulose nitrate is called nitration.

While the above equation is not universally accepted as correct, it does serve to illustrate the principle of the formation of cellulose triacetate. In actual practice the formation of cellulose triacetate is complicated somewhat by the fact that under the usual conditions of acetation, acetic acid is so weak that it will not alone unite with the cellulose to form the ester. It is, therefore, necessary to introduce the acetic acid group to the cellulose in a more energetic or reactive form, that is, as acetic anhydride and in the presence of a so-called catalyst, which will be considered more in detail later. Acetic acid is, however, usually present during the esterification and is also formed from the acetic anhydride during the process. This acetic acid acts as a solvent for the cellulose triacetate formed, rather than as the active esterifying agent.

While many other acetate processes have been developed and patented, as well as many modifications of the above, this general outline serves to illustrate the principle of most of them and it is useless to go into greater detail in the present Chapter. Suffice it to say that the effort in every case is to combine the cellulose with the acetate group with as little disturbance (degradation) of the large cellulose molecule as possible.

In order to obtain the desired product, cellulose triacetate, as quickly and easily as possible, it is the common practice to use in the acetation a suitable so-called "catalyst." Now the definition of a catalyst is: "A substance which brings about or increases the speed of a chemical reaction without itself being permanently affected by the reaction." In a chemical sense probably none of the so-called catalysts used in the acetation of cellulose come within the strict meaning of the above definition. However, the term "catalyst" was first applied to these *assistants* in this reaction and the term still lingers. For this reason only we will continue to speak of them as catalysts. Their true function, probably almost with-

out exception, is to cause a decomposition or degradation of the cellulose molecule to give a product, probably a "hydro-cellulose" or cellulose dextrin, which is chemically more reactive to acetic anhydride, or more ready to accept the acetate group, than the original cellulose. The extent of this degradation varies with the conditions, such as time, temperature, the nature and amount of catalyst present, etc.

In every process for the acetylation of cellulose some degradation of the cellulose occurs and the principal object of much of the research, as well as many of the patents, on the preparation of cellulose acetate has been to limit this decomposition just as much as possible, and at the same time to secure a complete and uniform esterification just as quickly as possible. The result is that a number of catalysts have been proposed and used to a limited extent. One of the first proposed was sulphuric acid and today it, or its compounds, are almost universally used in the commercial acetylation of cellulose. Among the other suggested catalysts, probably zinc chloride and sulphur chloride have received the most attention but they are seldom, if ever, used commercially.

While probably not identical with any of the processes in industrial use, the following laboratory methods illustrate the manufacture of cellulose triacetate.

Treat 100 grams of purified cotton cellulose, containing 5 or 6 per cent of moisture, with 400 grams of acetic acid and 5 to 10 grams of sulphuric acid at room temperature for 15 to 60 minutes. Place the mixture in a jacketed vessel, known as an acetylizer (see Fig. 116), arranged so as to hold the temperature below about 30 degrees Cent. (86 degrees Fahr.) and while agitating, intermittently and slowly add 400 grams of acetic anhydride. Allow this to stand at room temperature until the fibrous structure of the cotton disappears and solution of the cellulose appears to be complete. The result is a thick syrup which may be thinned with acetic

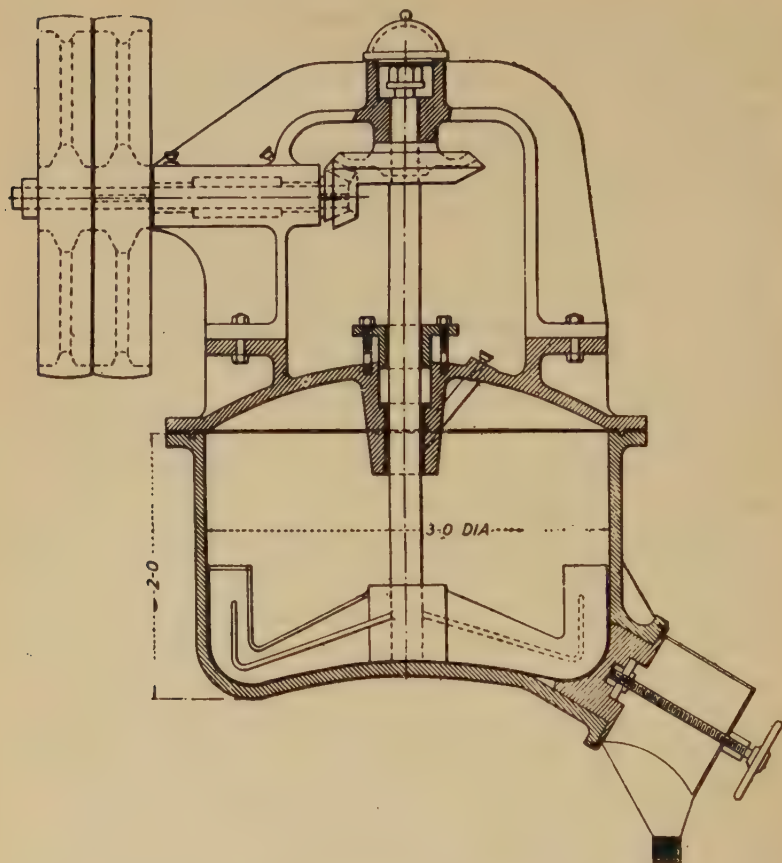


FIG. 116. Acetyler Mixer for Cellulose Acetate. (Courtesy of Lenox Foundry Co.)

acid. The usual commercial acetate process requires 6 to 12 hours, but at the above temperature a considerably longer time is usually required. The reaction is accelerated by increasing the temperature, but the product is not identical with that obtained at the lower temperature.

Miles's original process consists of treating 100 grams of dried and scoured, preferably bleached cotton, cellulose at a

temperature below 40 degrees Cent. (104 degrees Fahr. with a mixture of 270 to 310 grams of acetic anhydride, 390 to 410 grams of glacial acetic acid, and 3 to 9 cubic centimeters of concentrated sulphuric acid, while allowing the temperature to rise to 50 degrees Cent. (122 degrees Fahr.). As heat is evolved during the reaction, the temperature is at first controlled by cooling. When the heat evolved is no longer sufficient to maintain a temperature of 50 or 55 degrees Cent. (122 or 131 degrees Fahr.), the mixture is gently warmed and held at this temperature for 36 to 40 hours, or until the cellulose is apparently in solution, forming a heavy, nearly transparent, light brown mass. A test portion is then removed, precipitated in a large bulk of water, washed neutral and dried, when it should be completely soluble in alcohol-free chloroform but practically insoluble in acetone. If the primary or chloroform-soluble variety of cellulose acetate is desired, these solutions are treated as described in D, step C being omitted.

C. If the secondary or acetone-soluble cellulose acetate is desired, instead of pouring the acetic acid solution of the cellulose acetate into water, it is thinned somewhat with acetic acid and some water, with or without other acid, added. Care must be taken during this addition to avoid precipitation of the acetate. This solution is allowed to stand at room temperature. From time to time samples are withdrawn, precipitated by pouring into water, washed, etc., as described in D, and tested for solubility in acetone or other solvent.

Miles's original process consists of slowly adding a mixture of 60 to 65 cubic centimeters of water and 60 cubic centimeters of glacial acetic acid, per 100 grams of original cellulose, to the above mass while stirring vigorously to avoid precipitation. This mixture is held at 40 to 50 degrees Cent. (104 to 122 degrees Fahr.) for 12 to 16 hours, or until a precipitated, washed and dried sample is only plastic in warm

chloroform but is entirely soluble in pure acetone. The product is then ready for precipitation and purification as described under D.

This step has been variously described by many investigators as a hydrolysis, hydration, ripening or saponification process. What actually appears to occur is a depolymerization, disaggregation, or peptization of the colloidal particles of cellulose acetate to smaller particles, which are more readily dispersed (or "dissolved") in the acetone. In every case, either in chloroform or in acetone, the cellulose acetate is merely in colloidal solution and the principal difference between the chloroform and acetone soluble types of acetate appears to be in the size of the cellulose-acetate particles (micellae). It is interesting to note, however, that most of these depolymerization processes result in a simultaneous splitting off of some acetate radicals from the cellulose acetate, usually so as to give a product intermediate between the tri- and di-acetates of cellulose, but apparently this factor has little bearing upon the change in solubility. The time required is usually 24 to 48 hours.

D. When the desired solubility, either in chloroform, acetone, or other solvent is obtained, the cellulose acetate solution is poured into water, which precipitates the acetate. The precipitate is separated by filtration, washed well with water and, if desired, the final traces of uncombined acids may be neutralized with a little sodium bicarbonate in solution. The excess of this reagent, and the salts formed, must be washed out of the cellulose acetate, after which it is dried. When the cellulose acetate is to be used in the production of acetate Rayon, the acetone soluble product is usually the one desired.

The Miles process gives a yield of 130 to 145 grams of cellulose acetate per 100 grams of original cellulose. The resulting white, fibrous flakes of secondary cellulose acetate are soluble in formic or acetic acid with some difficulty; but

less soluble in ethyl acetate, nitrobenzene, and pyridine. It is insoluble in water, ethyl or amyl alcohol, amyl acetate, carbon tetrachloride, benzine, benzene, toluene or xylene. It is plastic in hot chloroform; soluble in hot 70 per cent aqueous ethyl alcohol, from which it gelatinizes on cooling; plastic in glycerol at 125 degrees Cent.; and soluble in a mixture of ethyl alcohol and benzene, from which it is precipitated by cooling.

The washing operation must be very thorough, for if any free sulphuric acid remains in the cellulose acetate, the stability of the product is greatly impaired. Even more than the slightest trace of cellulose sulphate is very undesirable and will result in an unsatisfactory product. It is quite certain that any cellulose sulphate present in acetate Rayon very materially increases its affinity for the basic dyestuffs, so that unless this factor is very carefully controlled, an irregularly dyed product will result. The oxycellulose present also increases the affinity of the fibre for various dyestuffs considerably. Washing is usually conducted in a centrifuge.

The water used in the precipitation of the cellulose acetate, as well as the first washings for the removal of free acids, are saved and treated for the recovery of the acetic acid present. The efficiency and economy of this recovery step is one of the very important factors in the production of acetate Rayon at a reasonable cost.

Depending upon the temperature, variety and amount of catalyst used, relative proportions of acetic acid and anhydride to each other and to the cellulose, the amount of water present, time, subsequent treatment of the cellulose acetate, etc., a wide variety of products are formed, all of which differ somewhat from all others in certain properties. In fact, the avoidance of a variety of acetates is the principal concern of the acetate Rayon production.

It is possible to obtain acetates of cellulose soluble in alco-

hol, or even water, but these are useless for the production of acetate Rayon due to the great degradation of the cellulose. In order to obtain a high-grade synthetic fiber, it is necessary to have a very uniform grade of cellulose acetate, free from all traces of uncombined acids and particularly free sulphuric acid; and the cellulose molecule must not be degraded any more than is necessary. Acetates giving good and continuous films upon evaporation of the solvent to be used in dry spinning are usually satisfactory for the production of acetate Rayon, provided they maintain their flexibility and do not discolor with age. This latter defect is usually due to the presence of mineral acids, etc.

E. The preparation of the spinning solution from the dried cellulose acetate is a comparatively simple operation. The proper quantity of solvent solution, usually consisting largely or entirely of acetone, where the secondary cellulose acetate is to be dry spun, is added to the dried cellulose acetate in a suitable closed mixer, as shown in Fig. 114. The mixture is agitated until solution is complete, when it is run into tanks. From these tanks it is filtered in the usual manner and run into very large sealed storage tanks which also serve the purpose of blending the different lots of cellulose acetate, so as to give a more uniform spinning solution. The solution is permitted to stand long enough to allow the air bubbles to rise to the surface, or is subjected to alternate pressure and vacuum in order to assist the removal of air. This solution is very stable, but must be protected against the evaporation of the solvent. While acetone is the principal solvent used in the dry spinning of acetate thread, some other solvents or diluents, usually of higher boiling point, are sometimes used with it. In the wet spinning process numerous other solvents have been and are used.

2. The Spinning Operation in the manufacture of acetate

Rayon, by the dry spinning process, is very similar in principle to the dry spinning of nitro Rayon but at the same time differs from it very materially in the mechanical details involved. In both cases the cellulose solution is forced through fine openings into air which evaporates the volatile solvent present, but the mechanical details of the spinning chambers or boxes, the spinning holes themselves, the temperatures used, and many other details differ very considerably in the two processes.

The acetone-cellulose acetate solution is conveyed to the spinning machines from the storage tanks by the usual system of piping with compressed air, or pumps. Suitable pumps supply the desired accurately measured and constant quantity of this solution to the spinnerets, which need not be of a noble metal as the spinning solution is not highly corrosive.

In dry spinning the spinneret is usually arranged at the top of a high and long but narrow air chamber. See Fig. 117. This chamber carries circulating warm or hot air, the temperature depending upon the composition of the spinning solution, solvents used, spinning speed, length of travel of the filaments in the chamber, denier of the filaments, etc. The warm air coagulates the spinning solution as it leaves the spinneret, thereby forming the filament by the evaporation of the volatile solvent. The temperature, time, and length of travel in the air chamber should be sufficient to remove all of the solvent from the fibre.

In some types of acetate Rayon spinning machines, individual air chambers for each spinneret are not used, one large chamber or spinning box being used for a number of spinnerets. Some of these spinning chambers are quite high, the thread traveling about 15 feet before reaching the bobbin below the bottom of the box. These spinning chambers, as well as those for the individual spinneret, are provided with

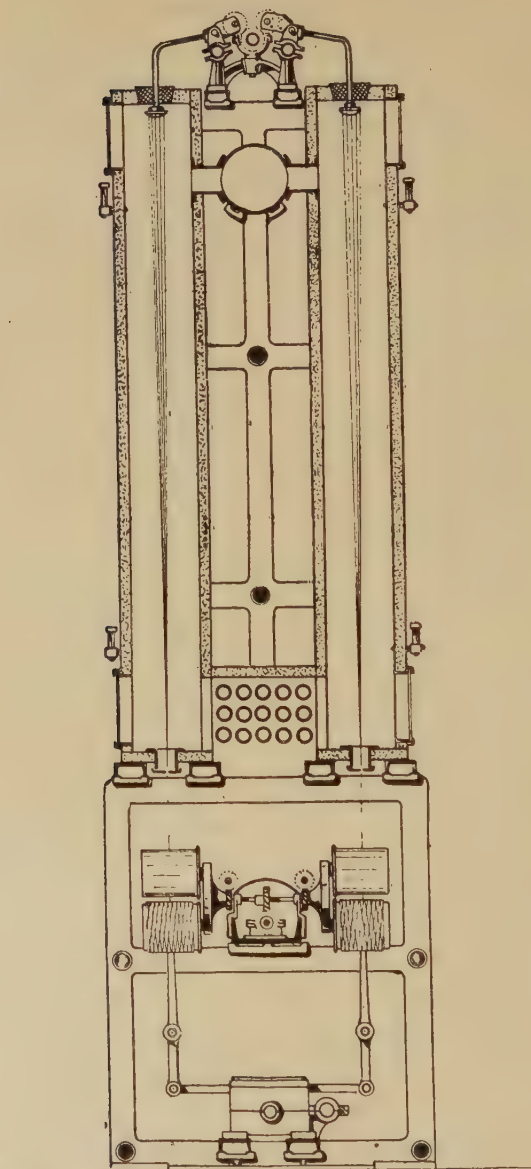


FIG. 117. Acetate Solution Spinning Machine. (Courtesy of C. G. Haubold A. G., Chemnitz, Germany.)

windows through which the spinner can watch the operation, air heaters, an air exhaust system for drawing the solvent-saturated air into the solvent recovery system, etc.

As the thread leaves the bottom of the spinning box it is wound, untwisted, upon a bobbin; or it may be wound into a centrifugal pot in the same manner as in spinning Viscose, with the desired twist. Where the bobbin system is used, the bobbins are spooled and the thread generally given about 2.5 twists per inch, on the usual type of Rayon twisting machines.

The acetate yarn is now ready for sale or use without any further chemical treatment. If desired, it can be wound into skeins, cops, cones, spools or in any other form. In the case of skeins, they are tied, graded and packed for shipment in the usual manner for all Rayons. Acetate Rayon is now available in any quantity in from 45 to 300 denier sizes, 2.5 turns per inch.

It should be noted that after spinning the acetate thread is immediately ready for use, without any further delay or expense in washing, desulphurizing or denitrating, souring, drying, etc. Furthermore, as the finished yarn does not have to be handled and treated as much as in the other Rayon processes it is injured less, and this results in a considerably smaller proportion of second-grade yarn. For this reason the expense of grading is considerably reduced. Also, the small quantity of waste produced in the acetate process can be redissolved in the solvent and mixed with the spinning solution for re-use.

As a result of these economies, while the principal raw materials, acetic acid, acetic anhydride and acetone, are comparatively expensive, as compared to the cost of the materials used in the Viscose process, the above savings entirely offset this increased cost and it is quite probable than an efficient acetate Rayon plant may at present be able to produce yarn ready for the market at about the same total cost of produc-

tion as a Viscose plant. It is very possible, too, that within the near future the production cost of acetate yarn may be even further reduced. However, as would be expected, it is at present practically impossible to obtain accurate data upon plant costs from the successful acetate yarn production.

The warm solvent-laden air from the spinning chamber is treated for the recovery of the acetone and other solvents either by refrigeration or by the absorption of the solvent in a suitable solid or liquid material, from which it is removed in a concentrated form on heating. As acetone is not exactly cheap, and about 4 to 6 pounds of solvent are used to make 1 pound of acetate Rayon, the efficient recovery of this material is quite a factor in the cost of the yarn. It is well known that great improvements and economy in the recovery of the acid and solvents used have largely been responsible for the present financial success of acetate Rayon.

Plant Design and Equipment.—In the usual acetate Rayon plant the preparation of the cellulose acetate, usually from linters which are purchased in the purified state, is an entirely separate and distinct operation from the spinning of the thread and the two operations are conducted in different buildings, both of which usually operate twenty-four hours per day. Smaller buildings are usually required for the power house, pumping station, refrigeration plant, water tower, laboratories, offices, etc.

The cellulose acetate building should be forty feet high, with steel construction, R. P. metal roof, concrete floors, tile walls, etc., all constructed to resist the acid fumes always present. Designed for 40 per cent windows and doors, the latter to be sliding doors, 9 feet high by 10 feet wide. This building should have two floors.

Equipment for the acetate plant will include:

1. Opening machinery for the purified linters.
2. Conditioning room, where their moisture content is properly regulated.
3. Jacketed acetating mixers.
4. Depolymerizing, hydrating or ripening tanks.
5. Precipitation tanks.
6. Centrifuges for filtering and washing.
7. Dryers for cellulose acetate.
8. Storage tanks for acetic acid, acetic anhydride, and sulphuric acid.
9. Storage tank for mixed acetating solutions.
10. Storage tank for sodium bicarbonate solution.
11. Weighing and measuring equipment.
12. Storage tanks for spent acetating solution.
13. Storage tank for weaker acid solutions for recovery.
14. Acid recovery evaporators, vacuum equipment, etc.
15. All miscellaneous equipment, such as piping, electric motors, lighting and wiring, trucks, cranes, cans for transporting the finished acetate, etc.

The spinning building is approximately the same size as the acetate building, covering one floor, steel construction, tile walls, cement floor, and maximum lighting.

Equipment in the spinning building will include:

16. Storage tanks for acetone and other solvents, if any.
17. Storage space for the cellulose acetate.
18. Weighing and measuring equipment.
19. Mixing or dissolving agitators.
20. Filter presses.
21. Spinning solution storage tanks.
22. Dry spinning equipment, including warm air chambers, heaters, air circulating equipment, etc.
23. Thread gathering equipment, either of the bobbin or centrifuge type.
24. Thread twisting machinery, if bobbins are used.
25. Other winding equipment suitable for skeins, cones, cops, etc.
26. Solvent recovery equipment.

27. Miscellaneous, such as piping, electric motors, lights and wiring, trucks.

28. Inspection, packing and shipping equipment.

The usual steam and electrical power plant, warehouses, and other equipment, such as that for water supply and purification, machine shop, sewage system, etc., common to all plants are also of course necessary in any acetate Rayon plant.

CHAPTER XV

RECOVERY OF CHEMICALS AND VOLATILE SOLVENTS USED IN THE PRODUCTION OF RAYON

In the four distinct processes which have been analyzed in this volume, various chemicals and volatile solvents would be lost if methods had not been evolved to save them and thus reduce the cost of production of Rayon.

In the four processes we have the following principal chemicals and volatile solvents to consider:

1. In the Viscose Process—

- (a) Caustic Soda (NaOH).
- (b) Sulphuric Acid (H_2SO_4).
- (c) Carbon Bisulphide (CS_2).

2. In the Cupra-ammonium Process—

- (a) Copper.
- (b) Ammonia.

3. In the Nitro-cellulose Process—

- (a) The volatile solvent Ether.
- (b) The volatile solvent Alcohol.

4. In the Acetate Process—

- (a) Acetic Acid.
- (b) Acetic Anhydride.
- (c) Acetone.

I. RECOVERY IN THE VISCOSE PROCESS:

(a) Caustic Soda: Caustic Soda, a chemical very extensively used in the production of Rayon, has in the past been allowed to be lost in the waste water. This loss of caustic soda amounted to approximately one-quarter of the consumption of the chemical in waste solution.

Among the various methods devised to recover caustic soda there is a specially designed separated tank known as a "Dialyser," manufactured by Mather & Platt, engineers of Manchester, England, under the patents of Leonardo Cerini. With this apparatus a considerable economy in alkali is now made possible.

The apparatus (Fig. 118) consists of a tank or vat fur-

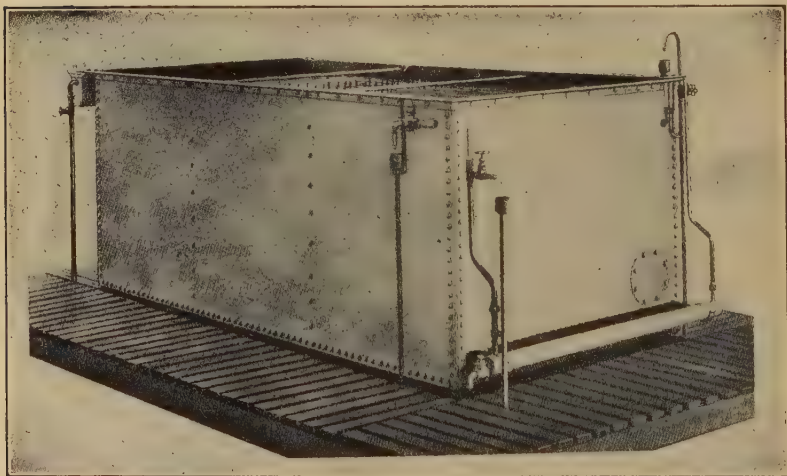


FIG. 118. Cerini's Dialysator with Collector. (Courtesy of Mather & Platt, Manchester.)

nished with inflow and discharge pipes and cocks and furnished with a number of diaphragms consisting of cotton cloths suitably treated.

The working of the apparatus is based on the osmotic exchange which takes place between the impure solution and water, through the semi-permeable membrane of the sack diaphragm consisting of cotton cloth suitably treated.

The impure solution which has an average concentration of 24 degrees Bé ($d = 1.200$) with about 16 per cent of NaOH, 2 per cent of carbonate and 2 per cent of organic matter, is brought into the dialyser in such a way as to fill up all the space around the outside of the diaphragm, the water is brought into the inside of the diaphragms, which are thus completely filled with a liquid which at first is water and afterwards pure soda solution.

In this manner, the water and the impure solution are separated from each other by the cloth forming the diaphragms, but at the same time they are also in contact with each other on a very large surface (about 180 square metres for each dialyser) of semi-permeable nature, and such as therefore permits the osmotic exchange and therefore the passage only of the sodium hydrate.

The sodium hydrate (NaOH), which is in the impure solution, passes therefore progressively into the water on the inside of the diaphragms, while the impurities, such as organic substances, coloring matters and also part of the carbonate of soda, are retained on the outside of the diaphragms and remain in the original solution.

The water, gradually becoming enriched with pure sodium hydrate is arranged progressively in layers, always more dense towards the bottom of the diaphragms, from which it is extracted in the form of the purest soda solution. On the other hand, the impure solution gradually parts with its sodium hydrate, being arranged in layers, becoming less dense towards the top, whence it is discharged, completely exhausted, through an overflow.

After filling, the osmotic exchange commencing and

the desired density obtained, the apparatus begins to work automatically. The discharge of the pure solution is regulated and the impure solution is fed as required.

The discharge of the pure solution at one end of the apparatus automatically draws the water from the small supply vat which communicates with the individual diaphragms. The level of the small vat is maintained constant by a ball tap which regulates the flow of water according to requirements.

The impure soda is led into the receiver by means of a pipe which enters at the bottom of the receiver, so that the heaviest layers are always at the bottom, while the highest density of the pure solution is found also at the bottom in the inside of the diaphragm at the same level.

Following herewith is an illustration, Fig. 119, showing the caustic soda recovery plant of the Snia Viscosa composed of the dialysers just described.

It is claimed that the Cerini Dialyser apparatus has an efficiency of 90-95 per cent, each unit recovering 88,000 pounds of caustic soda (NaOH) per year in pure solution. So it is only a question of the number of dialysers used to obtain recovery of this chemical for any capacity plant of Rayon production. From 16 per cent waste soda solution a concentration of 8 per cent is obtained, the pure soda recovered representing one-quarter of the total amount used in the Viscose process.

There were indirect methods used for caustic soda recovery. For instance, Professors Giordani and Cittadini of the Electrochemical Laboratory of the Royal Engineering School of Naples together with Soie de Chatillon and the Elettrochimica Pomilio of Naples have developed a direct use of this soda, which, it is claimed, has advantages over its recovery by other methods. The method put into practice by the two Professors above mentioned is through the use of the soda lye waste waters in the preliminary soaking oper-



FIG. 119. Cerini Caustic Soda Recovery Plant—Snia Viscosa, Italy.
(Courtesy of Mather & Platt, Manchester.)

ation when cellulose is manufactured by the chlorine gas process, which has been developed by the Elettrochimica at Naples, where celluloses are produced from various fibers such as Poplar and Esparto Grass by the action of chlorine gas by the Cataldi-Pomilio patents.

As it is known, in the first operation of the Viscose process where the wood pulp sheets are immersed in the apparatus known as a steeping press, about one-quarter of the soda used would be wasted, as it cannot be turned back into the manufacturing cycle owing to its high condition of hemicellulose.

By the Cataldi-Pomilio process 2.77 pounds of chlorine gas are necessary to produce 3.96 pounds of cellulose. In obtaining the above amount of chlorine gas 3.16 pounds of electrolytic soda are produced. To complete the cycle, therefore, for the production of 2.2 pounds of Rayon, a further 0.79 pound of caustic soda for the preliminary alkaline solu-

tion for the preparation of cellulose is needed. The remaining 0.79 pound of soda needed to produce 2.2 pounds of Rayon represents 36 per cent in terms of weight of the Rayon produced or, taking into consideration Italy's Rayon production at 30,000 tons annually, where this process of reclaiming caustic soda waste was applied, it would mean a production of about 11,000 tons of soda used by the Rayon industry, for which the corresponding production of chlorine gas would not be absorbed in the production of cellulose, but it can be stated, however, that a market can always be found for surplus chlorine gas.

Hence, a combination of the Rayon and electrolytic caustic soda industries would be advantageous, as it would assure the former a supply of cellulose and a profitable use of the waste soda, while it would assure the latter a satisfactory outlet for the chlorine gas obtained as a by-product of the industry.*

(b) As to the recovery of sulphuric acid which is used in the coagulating bath, few attempts have been made to reclaim this acid, as the percentage used is not sufficient to warrant the expense and the apparatus necessary for reclaiming it. However, it must be expected that in the near future when saving of the smallest amount will be considered as an important factor, technical precautions will be taken to reclaim such sulphuric acid which is now allowed to go to waste.

(c) In the manufacture of Viscose, carbon bisulphide, although by itself a powerful volatile solvent for many substances, does not behave as such, but forms with the cellulose and caustic soda a chemical combination (sometimes called cellulose zanthate, although its actual structure is not quite well known) from which cellulose is chemically precipitated by the acids and reagents contained in the spinning bath. The constituents of carbon bisulphide are liberated

* Reported from the Bureau of Foreign and Domestic Commerce, Department of Commerce, Washington, D. C.

under one form or another during the subsequent aging and spinning operation.

On the other hand, not all of the carbon bisulphide used in the process enters into combination with the Cellulose and caustic soda. A small proportion (10 to 15 per cent), which, in large scale production, may amount to a substantial figure, is certainly lost by evaporation in the course of various manipulations prior to spinning. The author knows of one company contemplating the recovery of losses from this source by absorption in a suitable liquid (Bregat Process), but results are not available at the present moment.

2. RECOVERY IN THE CUPRA-AMMONIUM PROCESS:

In order to keep the cost of the cupra-ammonium process within a figure that will permit successful commercial competition, it is necessary to recover the copper and the ammonia used. Figures vary on how much it is possible to recover, but it would seem that a fair figure is about 80 per cent of the copper and 40 per cent of the ammonia. The method of recovery varies with the process modifications in use. With caustic soda as a coagulating bath, it is possible to recover the copper by electrolysis and the ammonia by evaporation. If sulphuric acid is used as a coagulating bath it is possible to recover the copper by suspending bars of iron in the bath. The following method for the recovery of the copper and ammonia has been used:

The spent spinning bath containing copper and ammonia is run into a lead-lined tank of sufficient size. From there it is fed into an evaporator where under vacuum the water present is evaporated to concentrate the solution. After the desired degree of concentration has been reached the solution from the evaporator is run into a long shallow pan equipped with cooling shelves. This pan is lead-lined and

the cooling shelves are lead-covered to prevent corrosion. In this pan the copper and ammonia crystallize out in the form of a double salt. The acid is pumped back into the coagulating system and the crystals are shoveled into a hydro-extractor to free them from any excess acid.

These cupra-ammonium sulphate crystals are then placed in a tank and an excess of ammonia is added to precipitate the copper sulphate, which is then brought into contact with caustic soda and put through the cycle described in the earlier part of this process for preparing copper. The copper so recovered is used again in the process. The ammonium-sulphate liquor is sent to a still, milk of lime is added to neutralize the sulphate, and aqua ammonia is recovered. There are other methods for the copper and ammonia recovery, several of which have been made the subject of patents.

3. RECOVERY IN THE NITRO-CELLULOSE AND ACETATE PROCESSES: *

While solvent recovery is not a vital necessity in the manufacture of Viscose, due to the comparatively small quantities of cheap volatile reagent involved (0.6 pound per pound of Rayon), it is of paramount importance in the manufacture of nitro-cellulose and acetate Rayon.

Each pound of nitro-cellulose Rayon takes about 3 pounds to 4 pounds of ether and 2 to 3 pounds of alcohol.

Practically all of this ether is vaporized in the atmosphere of the spinning machines before the filaments are wound on the bobbin, while the alcohol, being much less volatile, is only partly vaporized during that phase. Under these conditions the Rayon thread reaching the bobbin is still wet with alcohol and contains only a small proportion of ether. It is sometimes possible to recover this alcohol by winding the filaments in water and by distilling the resulting weak alcoholic liquor. If this is not feasible, the spools should be enclosed during wind-

* Courtesy of M. Roulleux of Bregat Corp.

ing and then stored in drying chambers methodically ventilated. The exit air should be used for the ventilation of the spinning machines to be later treated by a suitable solvent recovery process. This procedure would undoubtedly reduce the solvent losses to a minimum. The entire process can therefore be conducted in such a manner that practically all of the ether and the major part of the alcohol used in the process will be collected under the form of vapor diluted with large quantities of air (0.15 to 0.3 gallon of solvent per 1000



FIG. 120. Enclosed Spinning Machine.

cubic feet of air). The economical recovery of these solvents under a refined liquid form suitable for re-use in the manufacture is a vital problem to the industry, and it is not surprising to find that considerable effort has been made in the past in order to find a satisfactory solution. The same considerations apply to the recovery of acetone and alcohol vapors lost in similarly large quantities in the manufacture of cellulose acetate silk.

A brief review of the various processes suggested or applied before the War to accomplish this purpose can be found in the article by Henri Barthelemy, published in the French magazine, "Le Caoutchouc et la Gutta Percha" (July 15, August 15, October 15, 1914—Item No. 1 of Bibliography). The author describes various methods with particular reference to the problems encountered in the manufacture of Rayon and divides these methods into the following classes:

Chemical Processes by absorption in chemically active liquids	{ Absorption of ether and alcohol in sulphuric acid hereafter described
Physico-chemical Processes by adsorption in chemically inert liquids or by adsorption in solids	{ Absorption of ether and alcohol in amyl alcohol Absorption of water soluble solvents in water Absorption of ethyl alcohol in soap Absorption in charcoal
Physical Processes	{ Electrostatic precipitation Condensation by ordinary cooling with or without ice machines Condensation by cooling at the very low temperatures produced by the expansion of the compressed gas mixture in a motor (Claude Process)

Yet, none of these systems was practical enough to be readily applied to the recovery of the huge quantities of ether and alcohol lost in the tremendous War production of smokeless powder.

The manufacture of smokeless powder bears a very close relation to that of nitro-cellulose Rayon, in that the same raw materials are subjected to similar treatments. Thus, the production of each pound of French smokeless powder B takes

0.85 pound of ether and 0.45 pound of alcohol, while the manufacture of 1 pound of British Cordite R. D. B. involved the consumption of 0.38 pound of ether and 0.27 pound of alcohol. As in the case of nitro-cellulose Rayon, only a small proportion of this solvent is to be found in the finished product, since it is almost entirely removed by vaporization in the atmosphere. At the end of the War 20,000 tons of alcohol or rather their equivalent in the form of ether and alcohol, were used every month in the French explosive works alone.

SULPHURIC ACID ABSORPTION PROCESS

It was hoped, at the beginning that the difficulties encountered in the application of the sulphuric-acid absorption process would be ultimately overcome. Considerable time and money were lost in futile efforts to perfect the system, which was finally abandoned by the Allied governments, in spite of the huge capital already invested in solvent recovery plants of this type.

It will be seen from these conclusions that the recovery of ether and alcohol by absorption in sulphuric acid or in water is merely of historical interest, although certain nitro-cellulose Rayon companies still claim to use sulphuric acid with advantage.

Briefly described, the sulphuric acid process as applied to the nitro-cellulose Rayon production consists in scrubbing the air carrying vapors of ether and alcohol evolved on the spinning machine by concentrated sulphuric acid, in acid proof towers (Gay-Lussac Towers) and subsequently distilling the absorbed ether and alcohol from the enriched acid which can be re-used in the next absorption cycle.

In spite of the difficulties resulting from the corrosive properties of sulphuric acid, it would seem from the above, that the process could be made both practical and efficient,

were it not for the necessity of using highly concentrated acid (at least 70 per cent) in the absorption phase of the process, while the distillation phase requires a diluted acid (below 45 per cent).

In practice, the operation is generally conducted according to the flow diagrams below (Figs. 121 and 122).

For further details about the sulphuric acid process, the

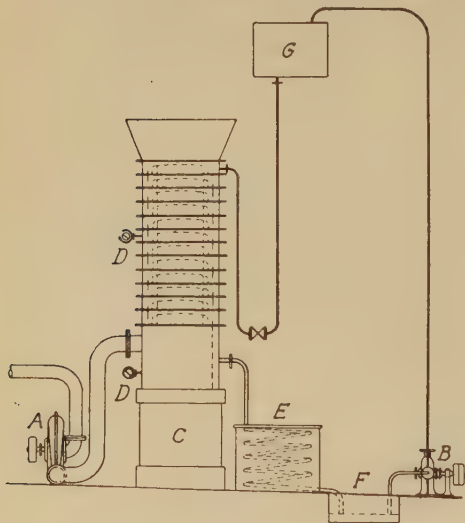


FIG. 121.

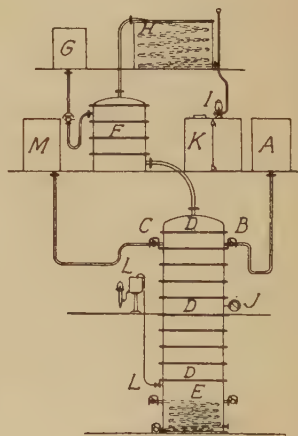


FIG. 122.

reader is referred to items Nos. 1, 2, 3, 4, 7 and 8 of attached Bibliography.

ABSORPTION IN WATER

Inasmuch as ether is only slightly soluble in water, this medium is utterly ineffective for ether recovery and therefore would leave the most important part of the problem unsolved. On the other hand the concentration of the alcohol vapors in the gaseous mixtures obtained in collodion silk manufacture is so low that it is barely possible to enrich the

liquor to an alcoholic content above 1 per cent and the recovery of this alcohol would hardly be profitable on account of the extreme dilution.

We have previously mentioned the Official British Solvent Recovery Pamphlet in connection with the sulphuric acid system of ether and alcohol recovery and the reader is referred to this document for further details about the comparative value of the water absorption process. (Item No. 8 of Bibliography.)

Water has also been suggested as an absorbing medium for the recovery of the acetone and alcohol vapors lost in the manufacture of acetate silk, but to our knowledge has not been used industrially, probably because in the absence of any chemical affinity, the gaseous mixture has been found too lean to permit an efficient and economical recovery.

In this connection, the author has in mind a certain explosive plant in Italy, recovering acetone by absorption in water artificially cooled to 40° Fahr. by means of ice machines. Twenty-four tons of water had to be cooled, circulated, heated and subjected to distillation every 24 hours in order to recover 900 pounds of acetone, representing a concentration of less than 2 per cent, yet and in spite of all these complications, the actual yield was found to be about 50 per cent.

ABSORPTION IN CRESOL (*Bregeat Process*)

Neither of the above two processes is efficient and practical enough to furnish a satisfactory solution to this most vital problem. The Bregeat process is discussed at greater length in order to fully outline one process and give all the phases of its operations. However, there are other such recovery processes in operation which are being successfully used.

If it were possible to find some cheap oil, having a marked

chemical affinity for ether and alcohol vapors, while at the same time permitting an easy release of the absorbed vapors by continuous distillation, without requiring any intermediate dilution and reconcentration or chemical treatment, it would be a simple matter to circulate this oil continuously in a closed circuit comprising an absorption unit and a distillation unit, as is done in the case of the recovery of benzol from coal gas. Thus, a satisfactory solution could be evolved. All kinds of vegetable, animal, mineral oils were tried out experimentally during the War by the best talents of the allied countries in order to perfect a process of this kind. It was then found that the phenolic bodies (U. S. Patent 1,315,700—Bregeat) and more particularly commercial cresol were best adapted to the purpose in view and a thoroughly satisfactory process (Bregeat process) based upon this discovery was created to fill the growing needs of the War industries. Fully a dozen sulphuric acid plants were scrapped or had their construction discontinued, in England alone, in order to make room for the vast program of expansion of this new process. The first French Bregeat plant was started in October, 1917, and at the time of the Armistice, six plants of this system were in regular operation, while three more were nearing completion, in France alone.

At the same time, it was found that the chemical affinity of phenolic bodies, and especially of cresol, was not limited only to the ether and alcohol solvents, but also applied to the acetone lost in the manufacture of acetate silk, as well as to all water miscible solvents used in the various pyroxlin and plastic industries. This property found its application in the recovery of the solvents vaporized from airplane dopes.

At the present moment, the Cresol Absorption Process, has demonstrated its value in about 50 recovery installations in connection with a wide variety of industries.

So far, five Rayon companies have adopted the Process, to wit:

The Obourg Artificial Silk Works at Obourg (Belgium)
Nitro-Cellulose Rayon.

The Maransart Silk Works at Couture, Saint Germain
(Belgium), Nitro-Cellulose Rayon.

The Aceta—G.m.b.H. at Berlin, Lichtenberg (Germany),
Acetate Rayon.

The Enka Company at Arnhem (Holland), Acetate
Rayon.

Smith, Bulmer & Co., Ltd., Halifax (England).

Additional details concerning the theoretical principles underlying the cresol process can be found in the article by G. Weissenberger, described under Item 5 of attached Bibliography. This article furnishes considerable experimental data to show that the vapor pressure of binary mixtures of cresol with various solvents is considerably below the normal defined by Van't Hoff's law and draws the conclusion that a chemical combination takes place between the cresol and the solvents which explains the remarkable efficiency of the process.

Description.—Briefly described, with reference to the accompanying flow sheet (Fig. 123), the process, although en-

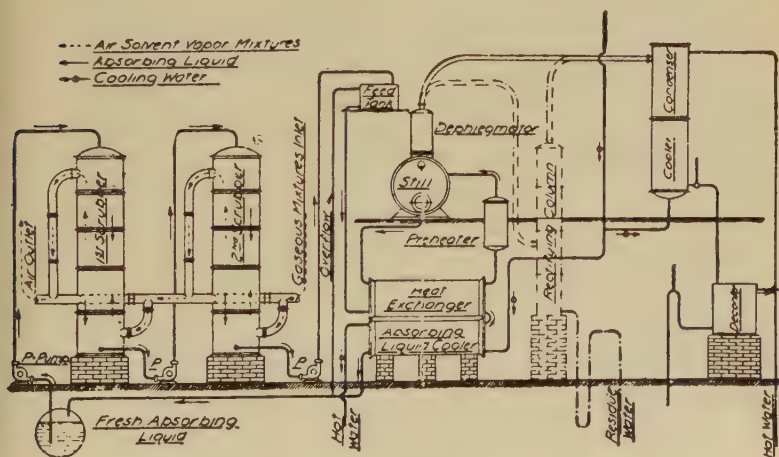


FIG. 123. Flow Sheet of the Bregat Solvent Recovery System.

tirely continuous in its operation, can be divided into three phases:

Absorption.—Crude commercial cresol is pumped from a storage tank to the top of the first scrubber and collects at the bottom from which it is pumped to the top of the second scrubber, while the air vapor mixture from the spinning machines is fed at the bottom of the second scrubber, escapes at the top and is brought back at the bottom of the first scrubber. The scrubbers are steel towers filled with a suitable baffling material such as the usual wooden grids of the benzol



FIG. 124. Solvent Recovery Towers in Nitro-Rayon plant.

industry or preferably special wire coils. Any necessary number of towers can be connected either in series or in parallel as local conditions and capacity may demand.

The descending stream of cresol keeps the filling properly wetted by a moving liquid film surrounded by the ascending body of gas in such a manner that the solvent vapors contained in the air vapor mixture are gradually and methodically absorbed in the cresol. The gas escaping at the top of the first scrubber has been in intimate contact with fresh absorbent and, subject to proper design and operation, is completely stripped from its solvent vapor content. On the other hand, the liquid collected at the bottom of the second scrubber, after having been in intimate contact with the fresh air vapor mixture direct from the spinning machine, is enriched to the maximum possible concentration.

Distillation or Stripping.—This enriched absorbent leaving the last scrubber is pumped to an elevated feed tank, and flows by gravity through a heat exchanger (Fig. 125), where it is methodically heated by the hot stripped absorbent discharged from the continuous still. It is then further heated by steam coils in a preheater and thence, discharged in the continuous still (Fig. 126), where all the solvent vapors are given off. The hot absorbent leaving the still is practically stripped from all traces of solvent and is re-used in the next cycle after having been cooled by the enriched absorbent in the heat exchanger and then by cooling water in the absorbent cooler.

The solvent vapors evolved from the still are accompanied with water vapor absorbed from the atmosphere treated and by traces of absorbent carried over from the still. The major part of these impurities is held back in the dephlegmator consisting generally of a short bubble plate column combined with a reflux condenser and an extractor.

Rectification.—The solvent vapor leaving the reflux con-

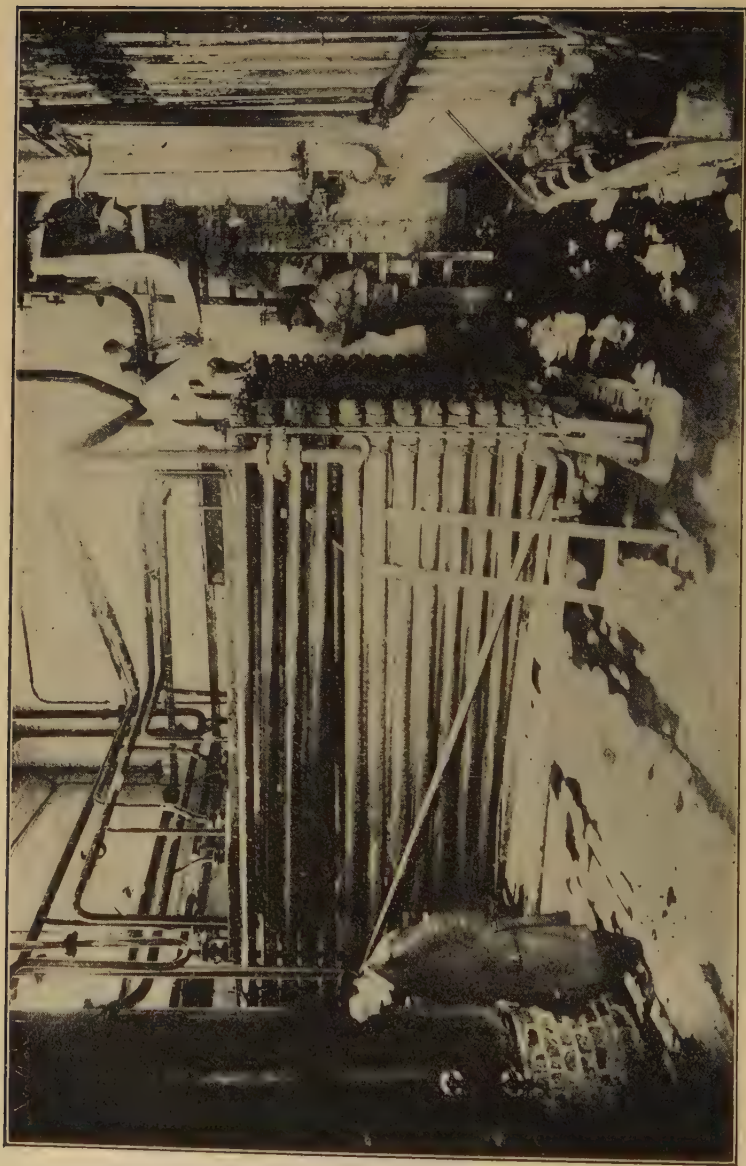


FIG. 123. Heat Exchanger.

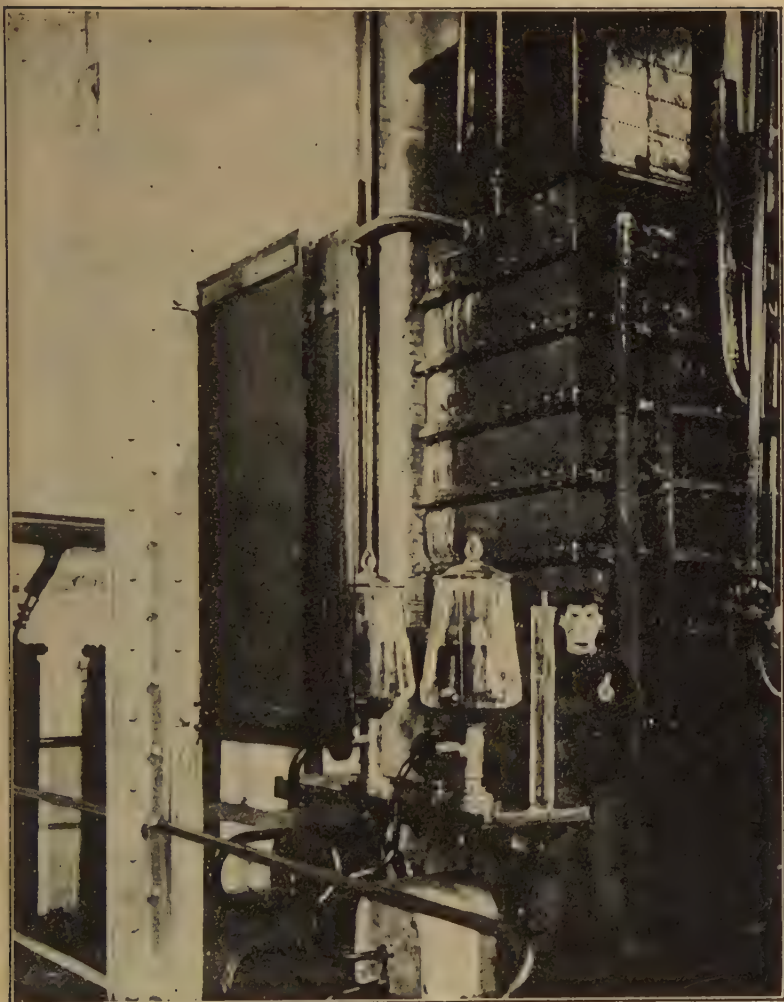


FIG. 126. Continuous Stripping Still.

denser is fed directly in a continuous ether rectifying column where the pure ether is separated from the mixture of alcohol and water. This mixture escapes at the bottom of the ether

rectifying column and is fed directly in a continuous alcohol rectifying column, where pure 190 proof alcohol is separated from the water.

The process is therefore entirely closed and continuous; the apparatus can be considered as a unit receiving the gaseous mixture at one end and delivering the pure solvents at the



FIG. 127. Continuous Stripping Still (another view).

other end, with no manipulation other than the occasional adjustments of pressures and temperatures.

When the process is applied to the nitro-cellulose industry certain precautions are necessary in order to prevent the deterioration of the absorbent under the action of certain oxidizing impurities contained in the atmosphere treated and traceable to imperfect nitration of the cellulose or to the use of old ether containing ethyl peroxide. Some difficulty from this source was encountered at the origin but has been successfully overcome.

First Cost—Operation Cost—Earning Power.—A complete solvent recovery plant of the cresol system, ready to operate, including piping, buildings, etc., will cost in the United States from \$20.00 to \$30.00 per pound of silk per 24 hours, depending on capacity and local conditions.

A plant of this type recovers continuously under a refined liquid form suitable for the immediate re-use in the production of Rayon, about 95 per cent of the solvent vapor contained in the atmosphere treated at a cost of 6 to 8 cents per recovered gallon (operating expenses only).

Tests conducted and endorsed jointly by representatives of the Bregeat Company and of the Aceta Company, at the latter Company's plant of Berlin Lichtenberg for fifteen consecutive days (from April 1 to April 15, 1927), showed the following itemized recovery cost per gallon of refined solvent:

	<i>Cents</i>
Steam, 28.63 lbs. at 5¢ per 100	1.43
Power, 0.49 KWH at 1.5¢	0.73
Cooling water at 60° F.—19 cu. ft. at 25¢ per M	0.48
Labor at 60¢ per hour : per gallon	2.29
Absorbent lost, 0.013 gallons at 55¢	0.73

Average American unit prices have been applied in this calculation. The labor item is unusually large, due to the

small capacity of the plant and in larger plants could be reduced to represent one-fourth or one-fifth of the above value.

As a result of 19 absorption tests, the absorption was found to be 98 per cent efficient.

Not all of the ether, alcohol, or acetone used in the production of Rayon can be collected as recoverable vapor in the atmosphere treated; some uncontrollable losses occur in the course of various manipulations, outside of spinning; on the other hand, a small proportion of solvents remains in the silk thread. A careful survey of actual operating conditions in nitro-cellulose Rayon works leads to the conclusion that a rational ventilation and drying system combined with the cresol solvent recovery process will recover fully 80 per cent of the total quantity of solvent used in the production of Rayon at a cost of 6 to 8 cents per gallon (about 1 to 1¼ cents per pound—operating expenses only).

Thus, for example, a nitro-cellulose Rayon plant, producing 10,000 pounds of Rayon per 24 hours, will require every day about 65,000 pounds of ether alcohol solvent representing a market value of \$7200. As stated above, it is possible to recover 80 per cent of this amount, *i.e.*, 52,000 pounds, worth \$5700, at a cost of say \$600 representing the value of about 5400 pounds of solvent. In other words, of the 65,000 pounds used in the manufacture, 20 per cent or 13,000 pounds will escape recovery and 5400 pounds (*i.e.*, 8.3 per cent) will be spent under the form of recovery costs, resulting in a total loss measured by the value of 18,400 pounds of solvent (28.3 per cent of total used).

Therefore, after having invested about \$250,000 in a cresol absorption plant (Bregreat Process) the manufacturer will be in the same position commercially as if he could buy his solvents at about 30 per cent of the market price without

any recovery. Actually 20 per cent would escape recovery at various points and would have to be replaced by outside purchase and the value of 8 to 10 per cent would have to be spent as recovery costs.

Another interpretation of these figures will show that the difference between recovered value and recovery cost is capable of amortizing the cost of the solvent recovery plant in a short time.

RECOVERY OF ACETIC ACID IN CELLULOSE-ACETATE RAYON PRODUCTION

In addition to its application to the recovery of acetone and alcohol lost in the manufacture of acetate Rayon, according to the procedure above described, with particular reference to the case of nitro-cellulose Rayon, the cresol absorption process in the vapor phase affords the apparently best method of reclaiming the acetic acid filtered and washed from the hydrolyzed cellulose acetate.

Briefly described, the process consists in scrubbing the acetic vapors evolved from the boiling weak acetic liquor with cresol, in a suitable scrubbing tower, whereby the acetic acid is absorbed and separated from the water vapor. Concentrated acetic acid is subsequently stripped from the enriched cresol in the usual manner.

SOLVENT RECOVERY PROCESS USING SOLID ABSORBENTS

Among the various solid absorbents (silica gel, ferro-hydroxigel, kieselguhr, activated carbon, etc.) which have been proposed in the last few years as solvent recovery mediums, activated carbon is the only one to have been commercialized, more particularly in the recovery of gasoline from casing-

head gas. It does not seem, however, to have gained favor in the Rayon industry, probably because of the following reasons:

(1) Like all other solid absorbents, activated carbon can only be used along a batch process. Referring to the diagram below, three absorbers filled with activated carbon are necessary to avoid interruptions. Only one absorber is used at a time for absorbing the solvent vapor from the gaseous mixture, while the other two absorbers are respectively being steamed (by means of both live and enclosed steam, to drive out the solvent vapor previously absorbed) and dried by a

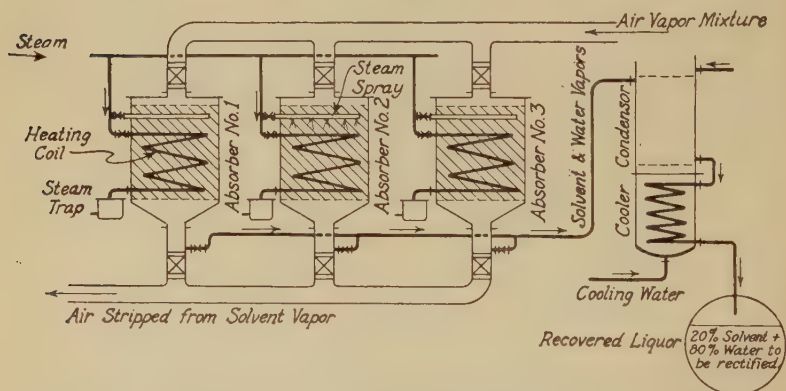


FIG. 128. Flow Sheet of Activated Carbon Plant for the Recovery of Water-miscible Solvents.

draft of air. All three operations proceed simultaneously and when they are completed, the gaseous mixture from the spinning machine is shifted to the absorber containing dry carbon, while the other two absorbers are respectively being steamed and dried, and so forth.

The process is therefore by no means automatic, it requires the constant attention of skilled operators and is rather erratic in its results. The recovered solvent is highly diluted with the water condensed from the live steam injected, requiring further batch rectification and purification before being re-used.

(2) In the course of time, activated carbon deteriorates and gradually loses its activity under the repeated action of air, heat, cold and live steam, with the result that a high efficiency cannot be maintained. The point is soon reached where it is necessary to renew the carbon at a high cost (about \$0.60 per pound in ton lots). The life of the carbon depends on many factors and may vary from a few weeks to a few months.

(3) The operating expenses, even exclusive of the cost of renewing the carbon, are comparatively high, due to the large consumption of steam and to the cost of the labor involved in the operation.

(4) Activated carbon exerts a catalytic action on certain vapors with the result that the recovered product contains various impurities requiring a chemical treatment and entailing additional loss and expense. This catalytic action accounts also for the rapid corrosion of the screens supporting and holding the carbon and this has proven to be a serious difficulty.

(5) Activated carbon is unsafe, more particularly when used in the treatment of combustible vapors mixed with air. Spontaneous combustions followed by explosions with casualties have been reported. The explosion of the Hasloch Powder Works in Germany on May 20th, 1926, related in item No. 12 of attached Bibliography is traceable to the use of activated carbon for the recovery of ether. The Hasloch plant is being rebuilt with the Bregat Process.

ABSORPTION IN SILICA GEL

This review would not be complete without the mention of silica gel as a solvent recovery medium.

Attempts have been made to recover the solvents by absorption in silica gel in Germany, according to a procedure similar to that described for activated carbon. A temperature of 750 degrees Fahr. was found to be necessary, for stripping the enriched silica gel from its solvent content, and the solvent obtained was highly contaminated with the products

of its partial decomposition, under the combined action of the high temperature and of the catalytic properties of silica gel. Even at atmospheric temperature during the absorption phase, silica gel was found to exert this catalytic action of the solvent vapor. The application of vacuum during the distillation phase was found to be of no avail and the process was definitely abandoned.

CHAPTER XVI

REPRESENTATIVE MODERN RAYON MILLS

RAYON plants, when compared with other industries, occupy vast areas. Design and construction of such plants represent the acme of scientific application to industrial development. All phases of engineering are enclosed within the walls of these industrial units.

As an example, there is the Du Pont Rayon Company's plant at Old Hickory where two manufacturing units put into operation in 1926 are shown in Fig. 129. The third unit is now completed.

Another instance of vast industrial plant development is represented by the Viscose Company of America which operates five plants, with new ones under construction one of which is a cellulose-acetate plant. It employs 15,000 people and has a production of over 50,000,000 pounds of Rayon per year. The Viscose Company is the largest producer of Rayon in the world. This company is now adding two more units, one to produce cellulose-acetate Rayon and the other for expansion of the Viscose Rayon output. Illustrations of the five plants are shown hereafter:

Another American plant which is now completed is that of the Industrial Rayon Corporation at Covington, Va. This plant is the second unit of this Company. The first unit has been in operation for some years at Cleveland, Ohio.



FIG. 129. Old Hickory, Tennessee, is spread out on a high bluff overlooking the beautiful Cumberland River. At one time a war plant village, Old Hickory now houses more than 4,000 employees of the Du Pont Rayon Company's plant and their families. The town has its own schools, churches, stores, theater and newspaper.



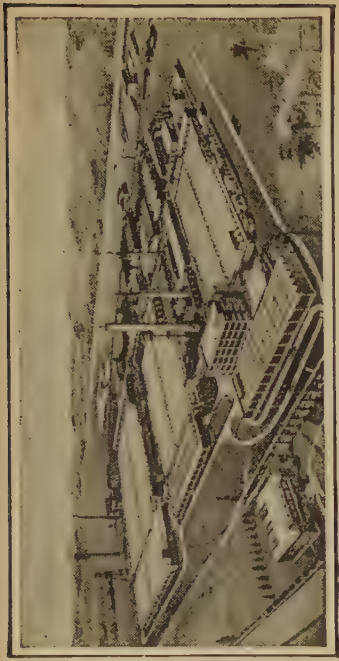
FIG 130. Du Pont Rayon plant in Tennessee.



FIG. 131. The Viscose Company original plant at Marcus Hook, Pa.



Lewistown, Pa.



Roanoke, Va.



Parkersburg, W. Va.



Pulp plant at Nitro, W. Va.

FIG. 132. The Viscose Company Plants.

LA SOIE DE CHATILLON COMPANY *

An outstanding example of a Rayon manufacturing organization is La Soie De Chatillon Company, whose name is derived from the Chatillon Castle, located in an Italian Valley where the French language has always been spoken. The author has gone into greater detail on the buildings of this company because he has had the unusual opportunity to visit and inspect them and also because this company put at the author's disposal the photos which are incorporated in this chapter. These were the only photos which we could secure which give a true picture of the largeness and magnitude of the problems of a Rayon producing plant from the interior. While there are now three distinct Rayon plants operated by this company, at Ivrea, Vercelli, and Chatillon, the latter was started first in the year 1921 in a very moderate commercial way, though laboratory work was commenced in the year 1918 with a small amount of capital. The importance of this Rayon organization can be appreciated both by recognizing the completeness of the plants and also by the large capital invested, which now exceeds 200,000,000 lire. The various companies named below are affiliated and operated in conjunction with the main Rayon plants:

The Viscose Rheinfelden at Rheinfelden, Switzerland, where artificial horsehair and straw are manufactured.

The Carlo de Sigis Company at Pavia, manufacturing carbon sulphide so much in demand by the Viscose process.

The Setificio of Pogliano at Milan supplying a wide range of raw and dyed silks.

The Industria Seterie Stampate, G. L. Tondani & Co., Milan, manufacturers of printed fabric.

The Filati Artificial Chatillon at Milan, which acts as the distributing organization.

* The material and illustrations on the La Soie de Chatillon Mills of Italy, were submitted to the Author by courtesy of Dr. Marcello Segre of the said company.

REPRESENTATIVE MODERN RAYON MILLS 613

The growth of the company can be shown by comparison between the years 1921 and 1925:

	1921	1925
Capital, lire	15,000,000	150,000,000
Hands employed	900	8,000
Land owned by the company		
in square feet	303,085	1,876,160
Area of plants, square feet..	85,994	444,596
Output in pounds	870,000	6,300,000

Since 1925, however, the capital of the company has been increased to 200,000,000 lire. The capacity of the plants also increased to 45,000 pounds daily, using about 17,500,000 gallons of water. To insure the most favorable conditions for manufacture any time during the year the atmosphere is renewed every five minutes all over the 120,000 cubic metres of the chemical section and every fifteen minutes throughout the 160,000 cubic metres of the textile works.

The extent of the works, which are located at Chatillon, Ivrea, Vercelli, Rho, Parabiago and Pogliano, represents an expanse of effort and capital rarely spent over so short a span of years—from 1918 to 1928—by any other industry.

A more complete analysis of the Chatillon works and operations would require considerably more space than is possible in this case. There are other Rayon organizations which can easily show equal or greater results, and the author would have been pleased to give such information as is presented here in the case of the Chatillon Company had it been obtainable. The author is glad of the opportunity to follow this brief outline of the successful efforts made by the Chatillon Company with a series of pictures showing the extent and type of their plants and completeness of design, as an indication of what would result in all cases of industrial development if proper consideration were given to the comfort of employees and the efficiency of mechanical and process operations.

These pictures tell a story of industrial advancement to all those associated in the enterprise, from the worker to the officials and stockholders.

The Rayon plant shown in Fig. 133 is built in the Valley of the Chatillon Castle. One can observe the quiet, retired spot where alone it is possible to bring together a group of people who could devote their time to pleasurable work in spite of the many technical difficulties. The atmosphere and the location of these plants permit of careful devotion to the creation of this interesting, delicate, and beautiful textile yarn.

Figure 134 gives a clear picture of the design and construction of the spinning sheds. It also shows the workers leaving the plant, with the Chatillon Castle far above on the left.

Figure 133 shows the Chatillon Control Laboratory. It is through this department that the quality of the spinning solutions and the spun thread are tested, and at stated periods of the day controlled. This laboratory is the master mind of the entire plant, where the ablest Rayon chemists are developed.

Figure 137 shows the Rayon Mills at Ivrea and Fig. 144 shows the other mills at Vercelli. It must be noted that each plant, though erected at different places follows the same type of design with consideration for efficiency in machinery, material handling and labor. Each of these mills has a capacity of about 15,000 pounds of Rayon per day of twenty-four hours.

Figure 136 gives a clear view of the arrangement, type and size of the tanks at the Chatillon Mills which carry and handle through automatic pump systems the solutions in the various stages.

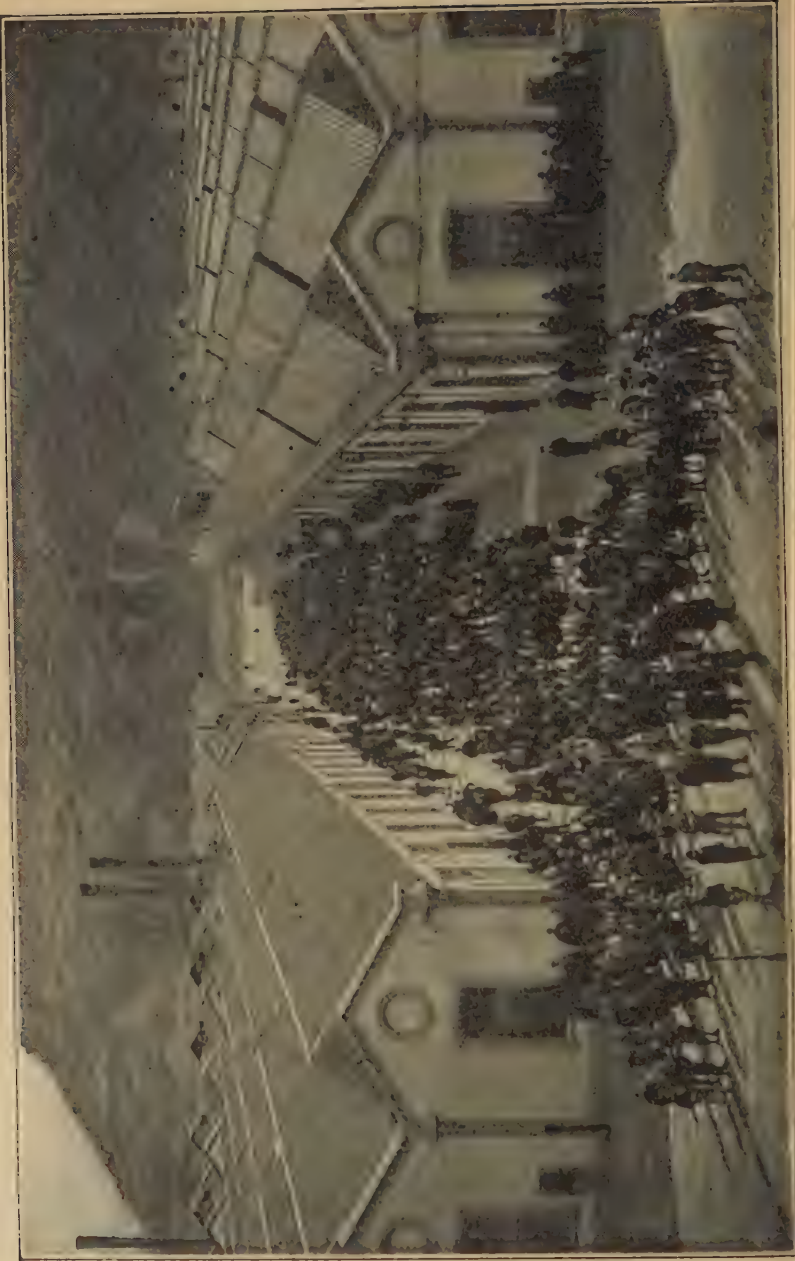
In Fig. 138 are seen the large acid tanks at the Ivrea Mills.

The alkali cellulose manufacture is shown in Fig. 139, illustrating the solution presses in operation at the Ivrea Mills.

Another outstanding example of plant design and construction are the plants of the Nederlandsche Kuntsijde Fabriek Enka, commonly known as "Dutch Enka." Fig. 151 gives



FIG. 133. View of the Mills at Chatillon, Italy.



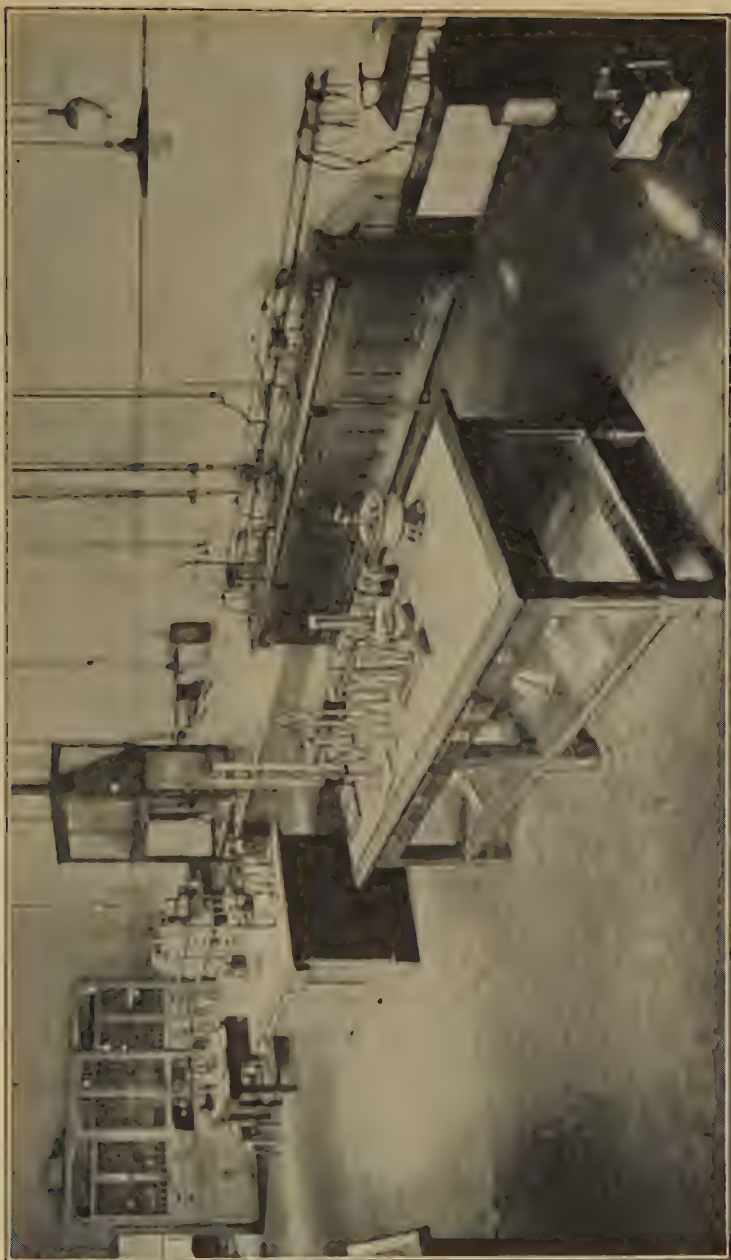


FIG. 135- Control Laboratories at Chertillon.

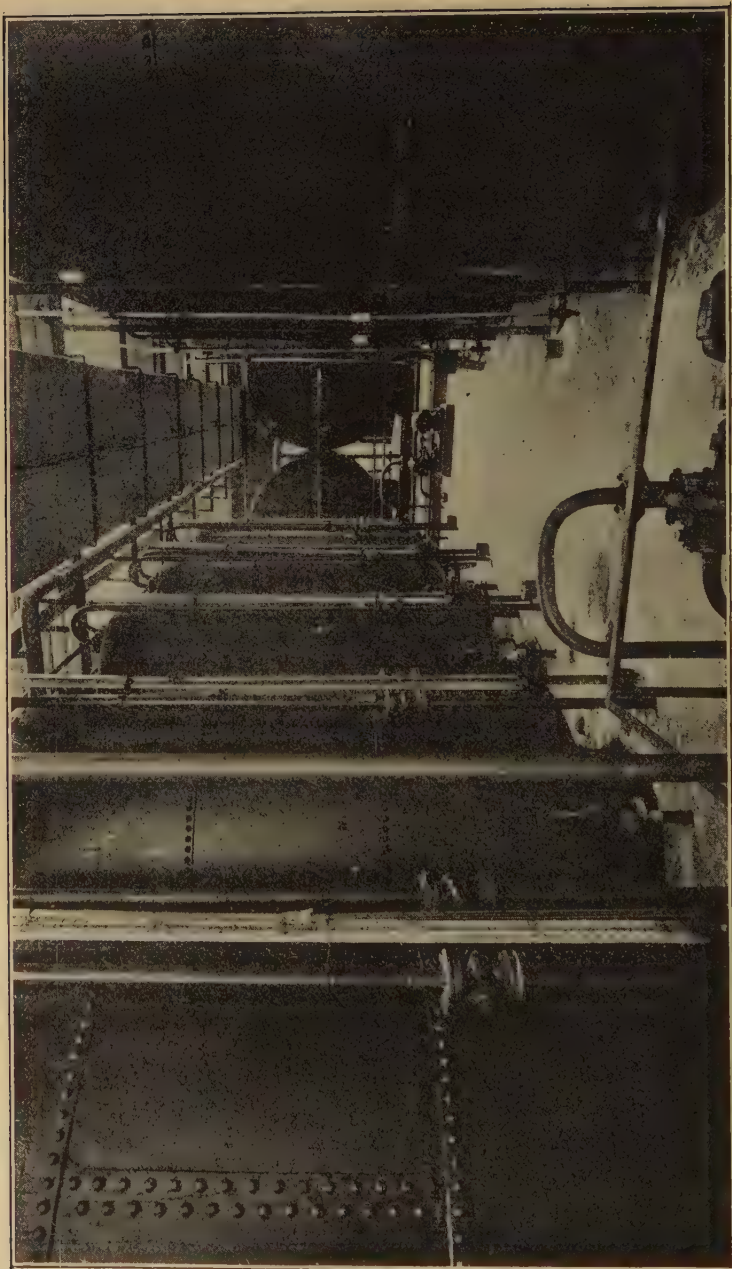


FIG. 136. Tanks at Chatillon Mills.



FIG. 137. General View of Ivrea Mills.

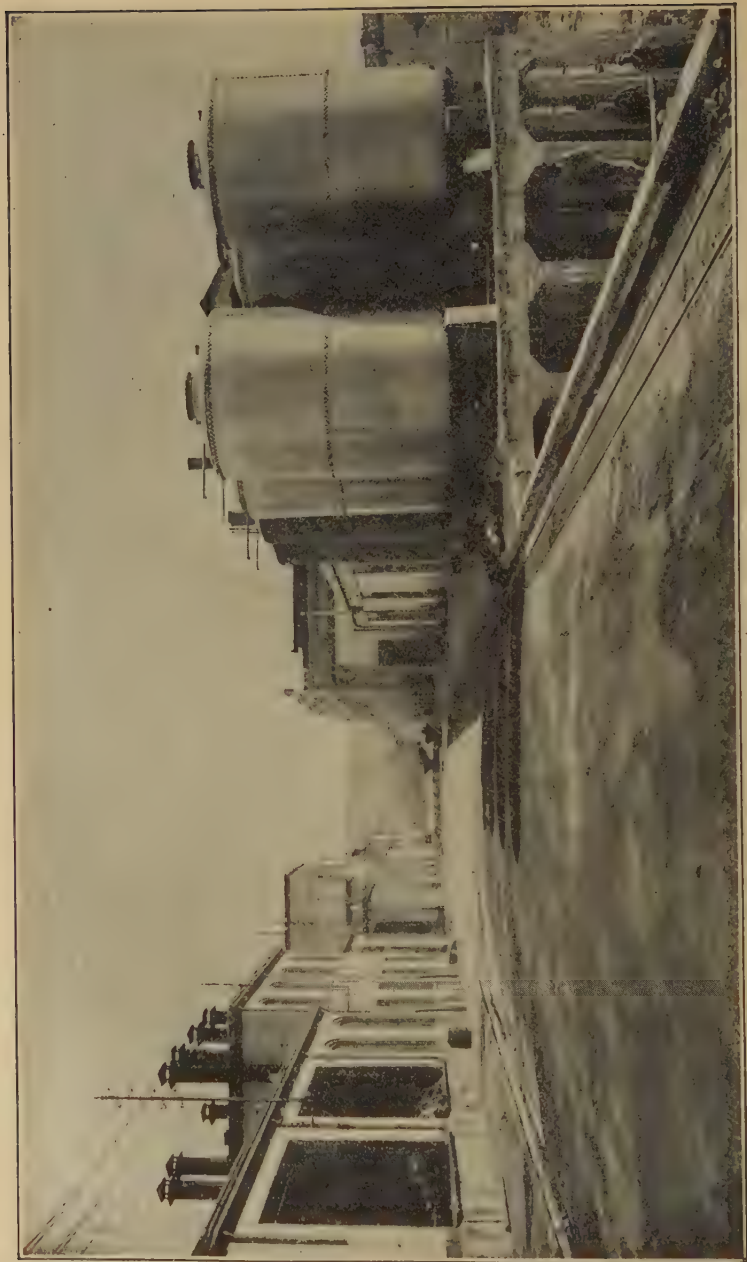


FIG. 138. Acid Tanks at Ivrea Mills.

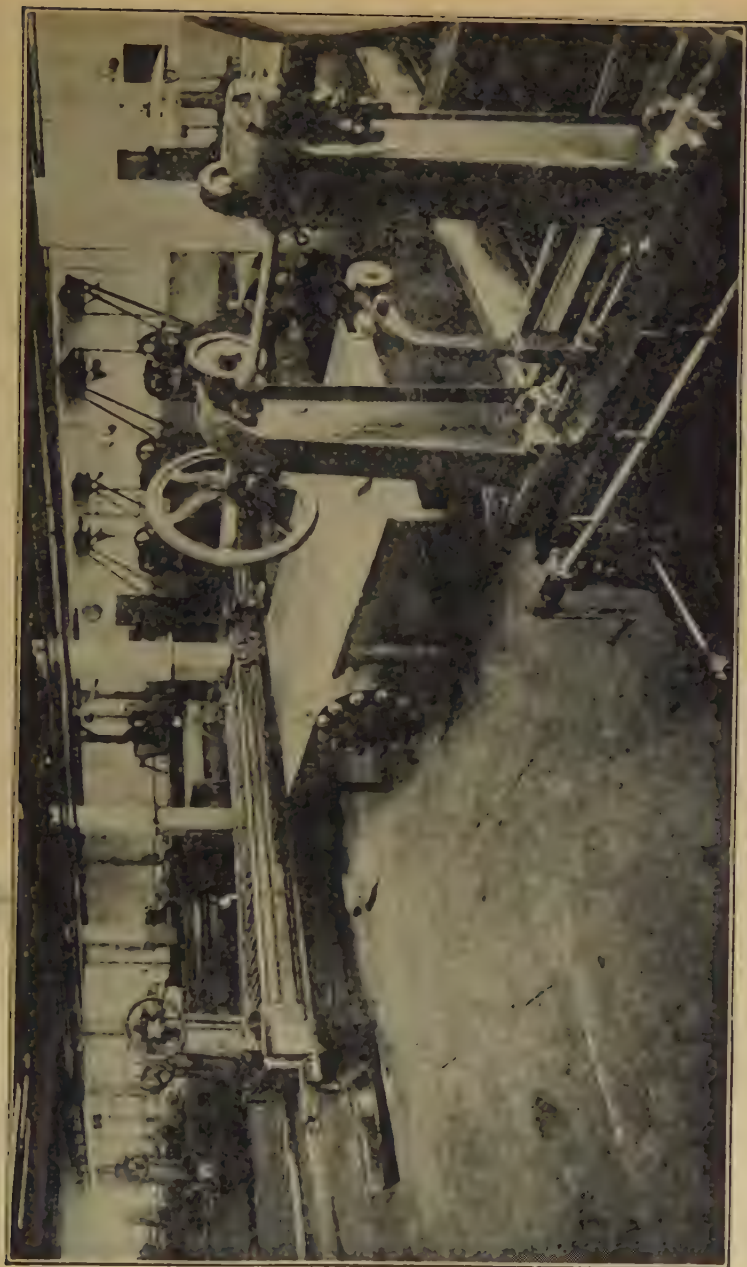


FIG. 130. Alkali-cellulose Process, Ivrea.

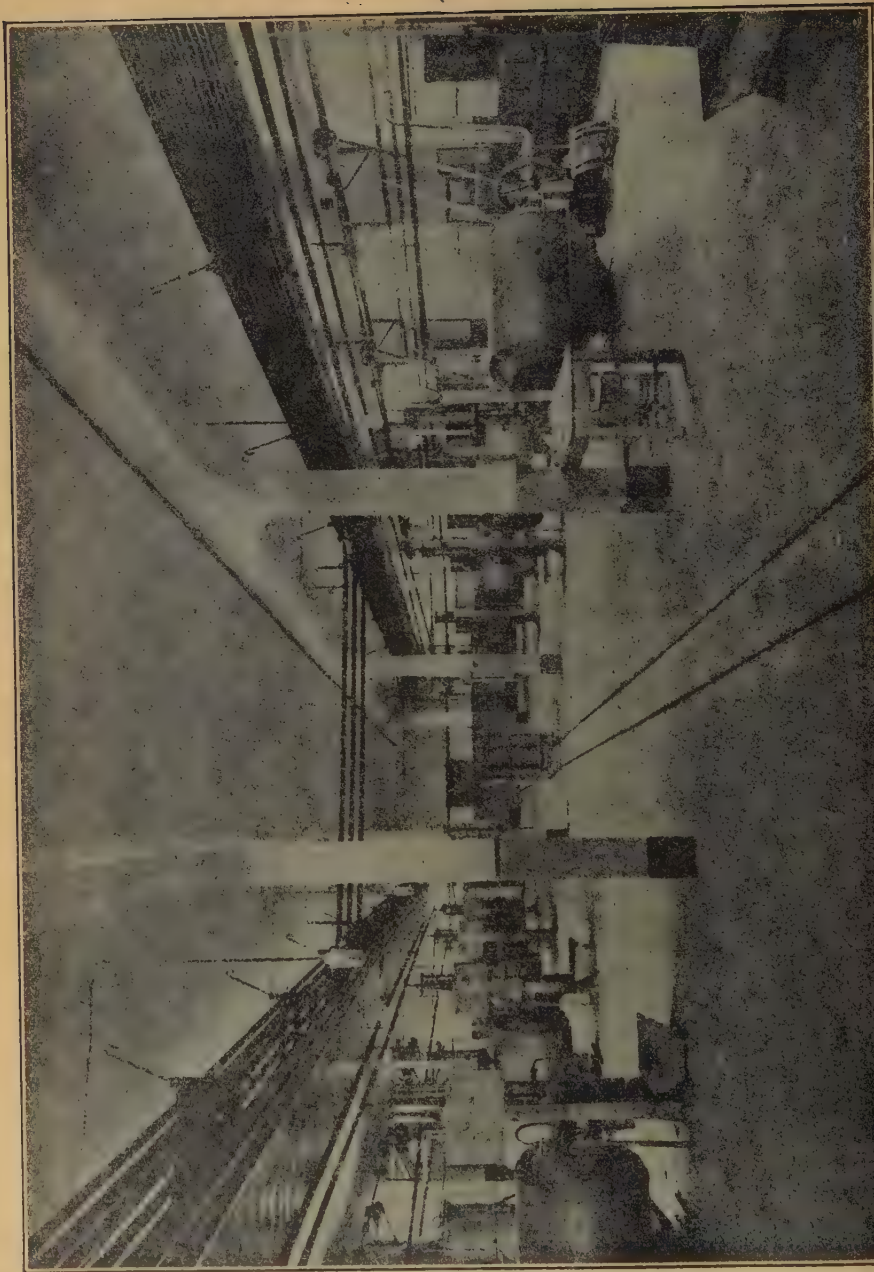




FIG. 141. Spinning Hall at Ivrea Mills.



FIG. 142. The Bleaching and Dyeing Department at Ivrea Mills.



FIG. 143. Sorting, Grading and Packing Hall at Ivrea Mills.

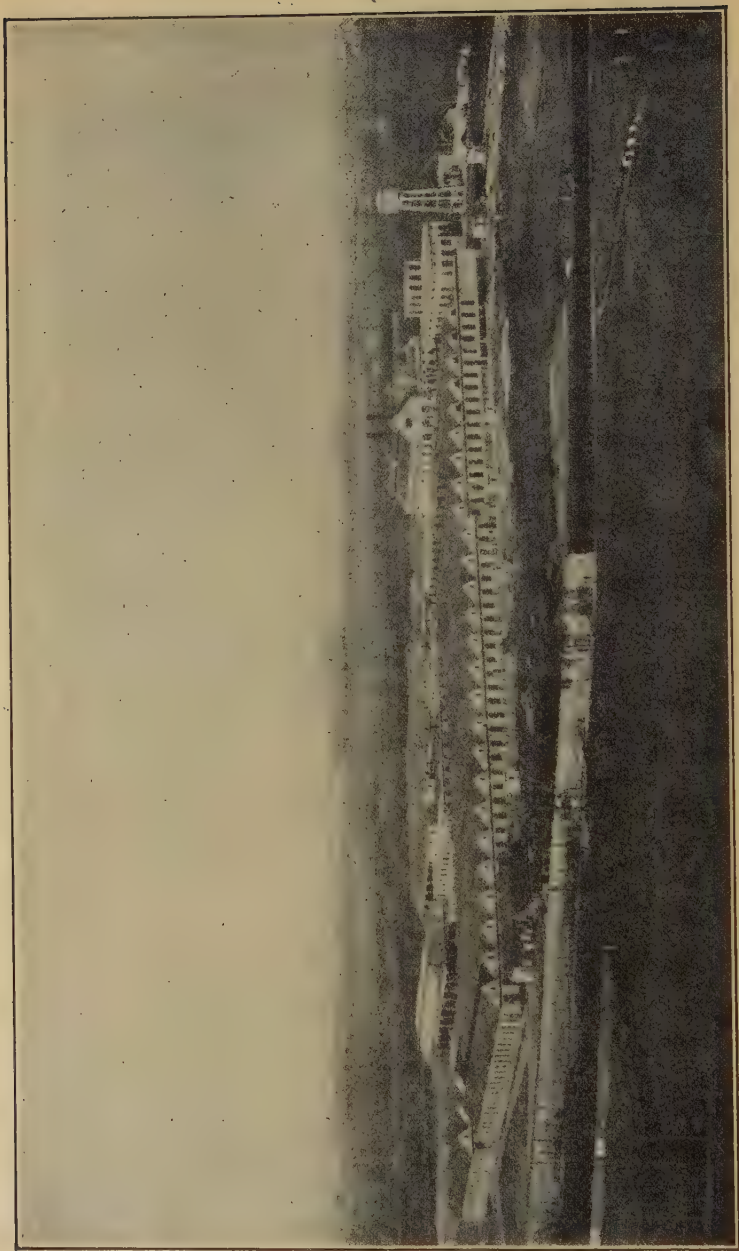


FIG. 144. General View of the Vercelli Mills.

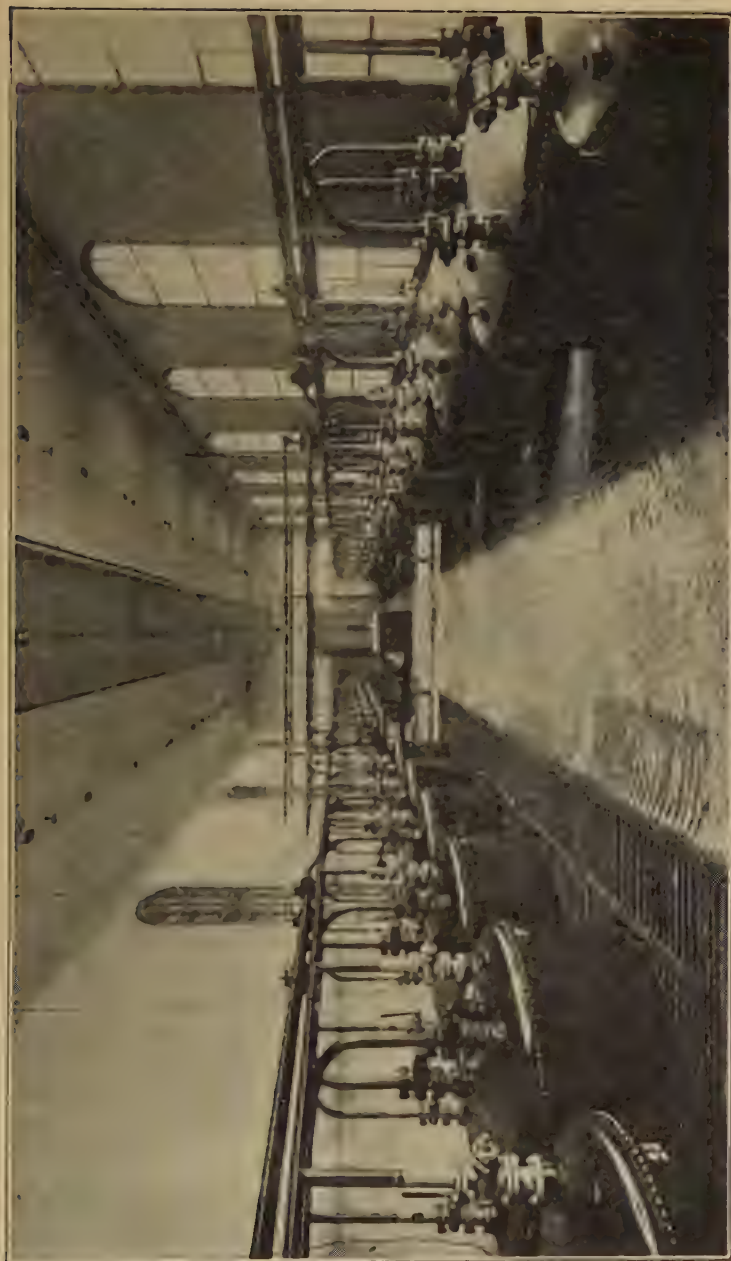


FIG 145 Viscose Ripening Tanks, Vercelli



FIG. 146. Bobbin Drying Hall at Vercelli Mills.



FIG. 147. Twisting Hall at Vercelli Mills.

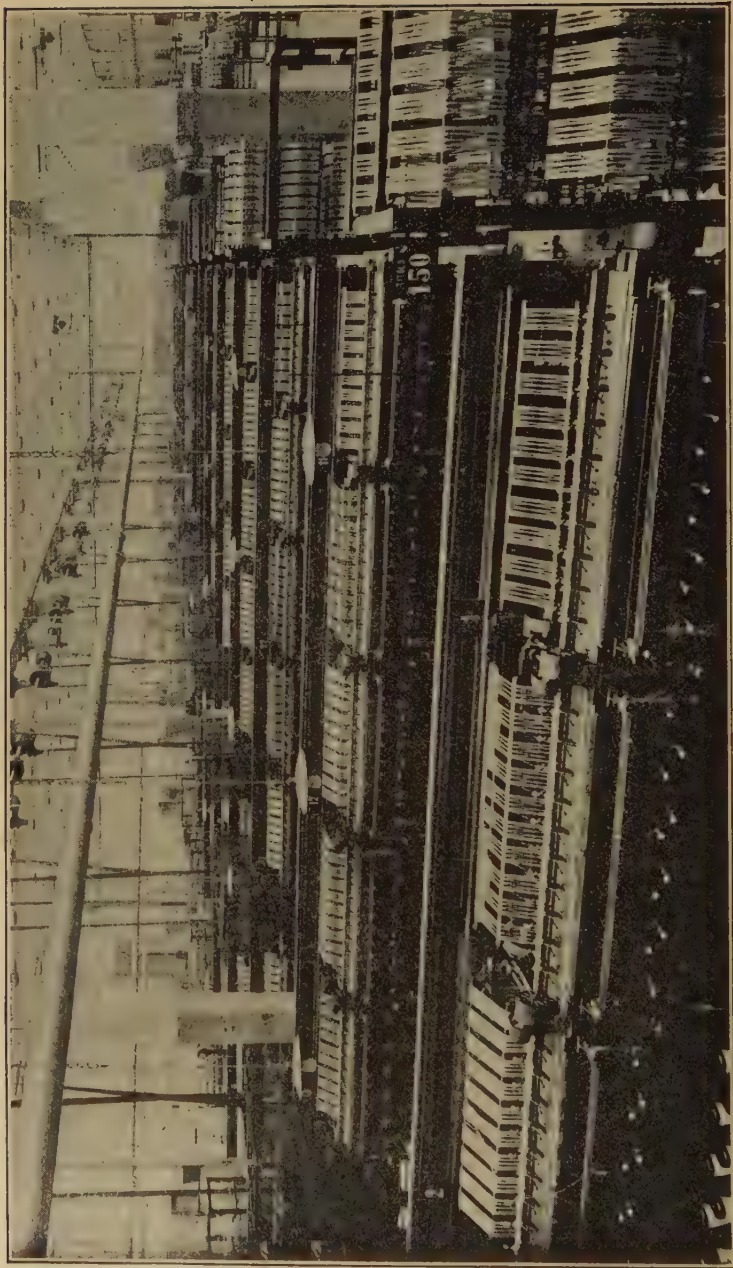


FIG. 148. Reeling Hall at Vercelli Mills.

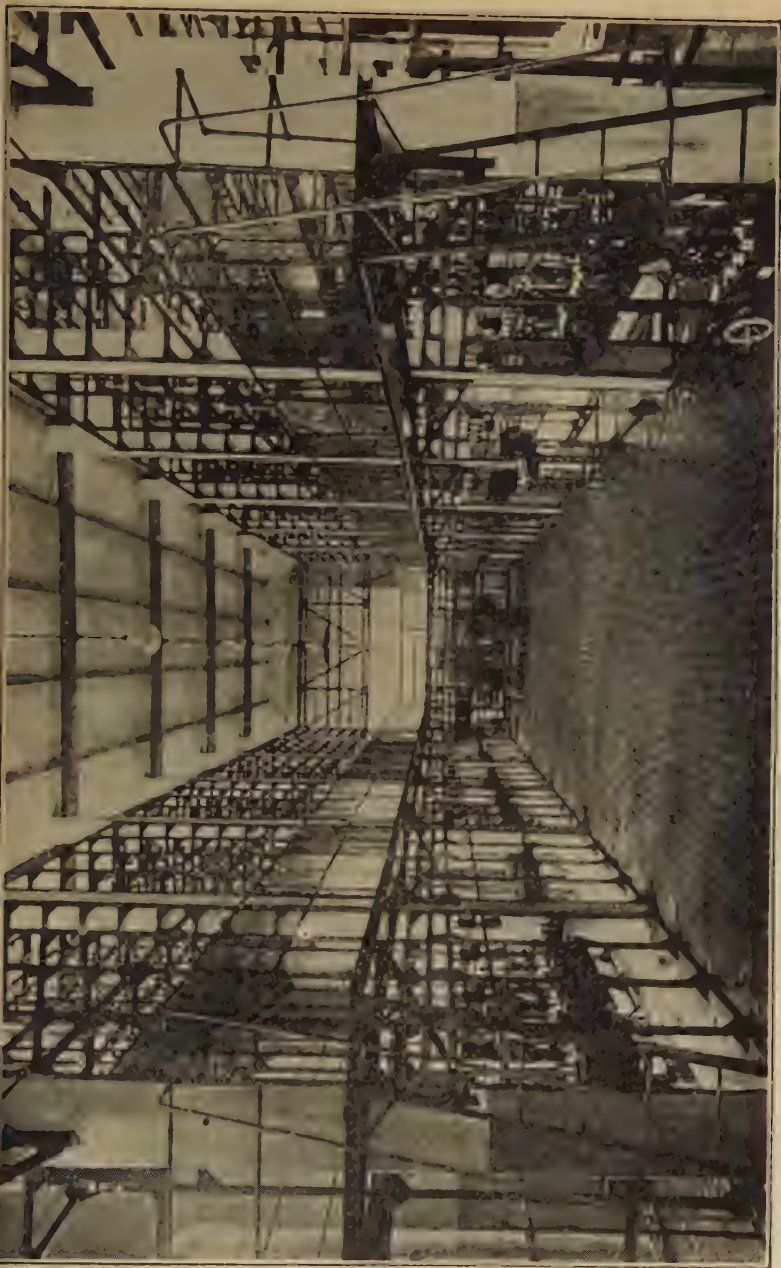


FIG. 149. Interior of the Power and Transformer House at Vercelli Mills.

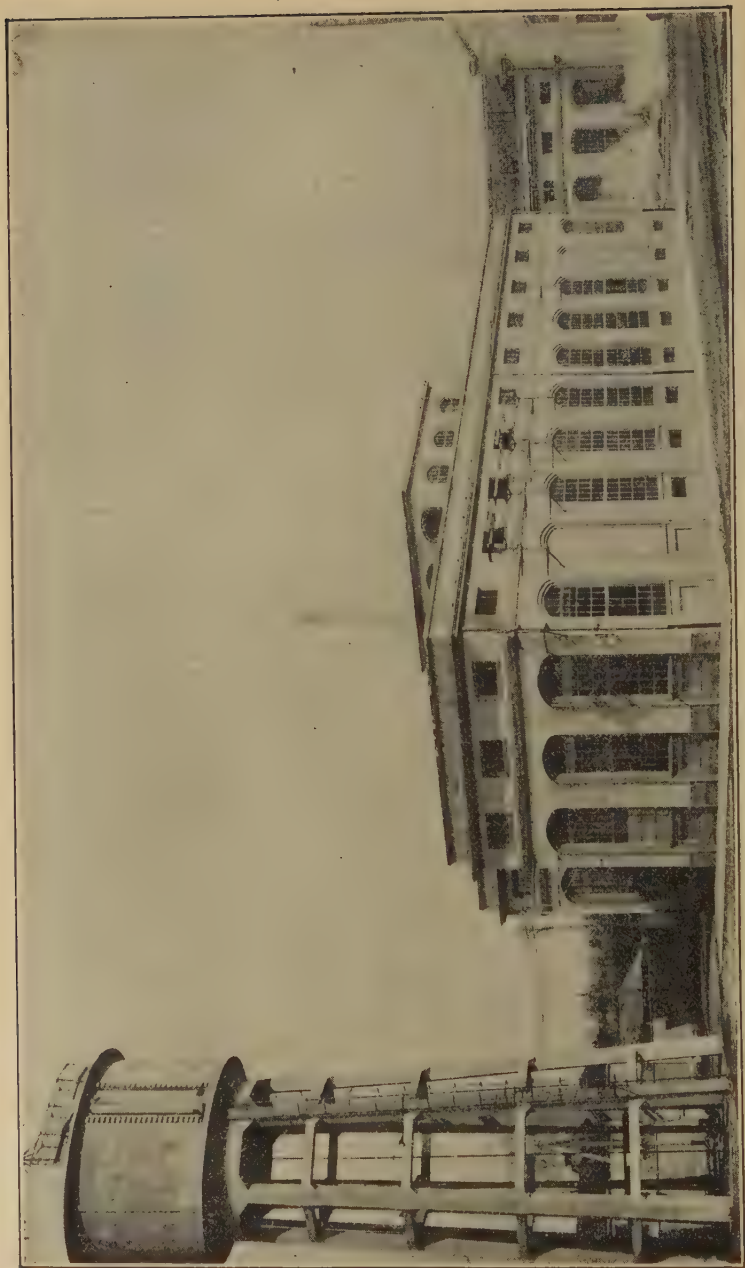


FIG. 150. The Exterior of the Power and Transformer House at Vercelli Mills.

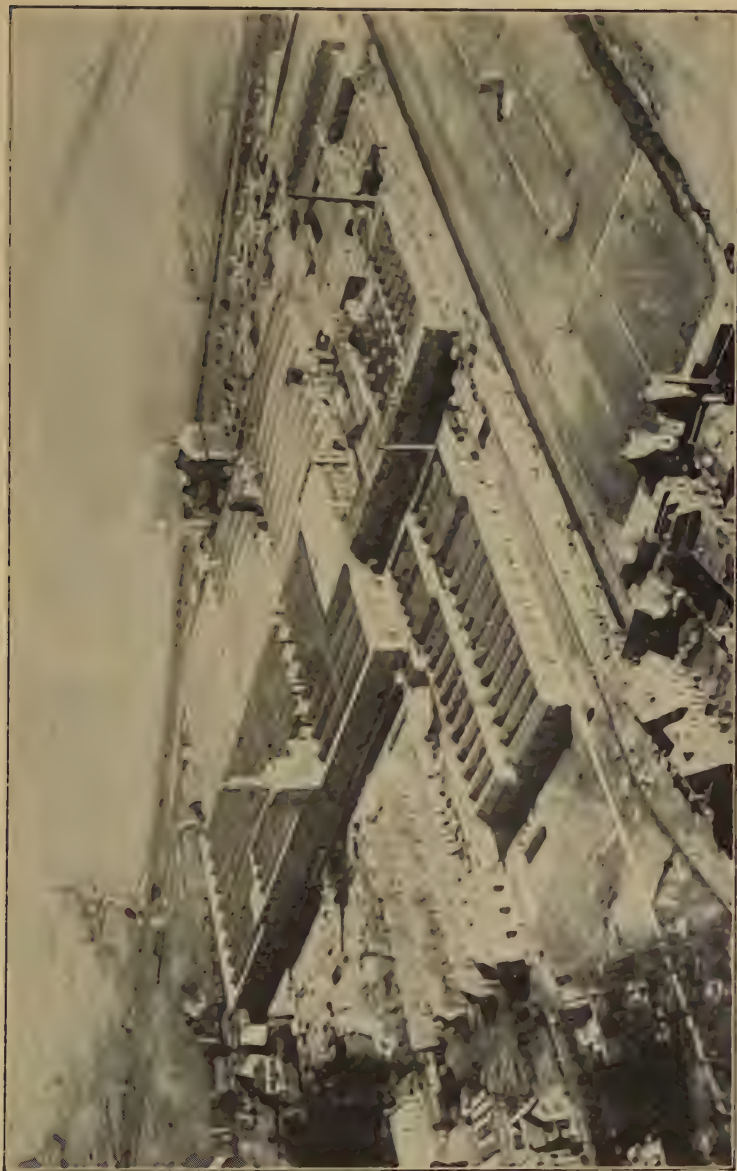


FIG. 151. Arnhem Plant of the Dutch Enka Co. (Photographs by courtesy of Dutch Enka air Photograph, K. I. M.)



FIG. 152. Ede Plant of Dutch Enka Co. (Photograph by courtesy of Dutch Enka Air Photograph.)

an airplane view at Arnheim and Fig. 152 a similar view at Ede. There is also a plant at Rotterdam.

Through a holding company controlled by Enka known as "Mackubee" the following are the main affiliations:

British Enka	American Glanzstaff
Italian Enka	American Enka
Société Lyonnaise	

Another example of an outstandingly modern Rayon plant is the Bemberg cupra-ammonium Rayon Mill at Elizabethton, Tennessee, Fig. 153. With a complete knowledge of technical details of the Rayon industry it is necessary to possess a keen insight of all the other numerous fine details that arise in selecting the location, constructing the buildings, selecting the equipment, and its proper allocation in the mills, and above everything the preparation of the labor, which must be intelligent and trained in advance in order that proper results may be obtained. Then comes the important consideration of capital which, as in no other industry, is required in amounts of millions of dollars rather than thousands.

It is important to note that the types of buildings constructed for Rayon production are now being developed along similar lines; in other words a standard for buildings, as also the arrangement of equipment is being recognized and put to practice without any specific understanding between the builders and operators of such plants. This applies to new mills. Where old buildings are considered they are used in part only for the chemical end of the process, offices, power and refrigeration plant but when it comes to that part of the process beginning from where the yarn comes into "being" and through all the textile operations until it is packed and shipped, an entirely new building is constructed along the established one-story, saw-tooth type shown in the above illus-

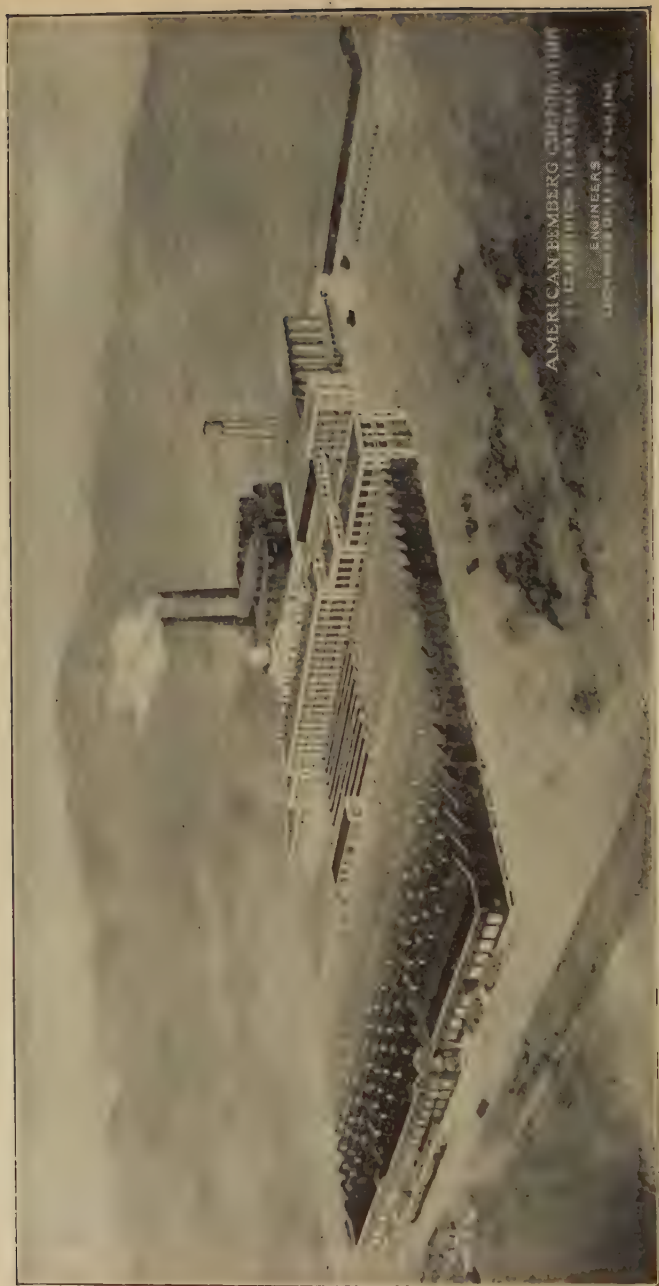


FIG. 153. American Benberg Rayon plant—Elizabethton, Tenn.

trations or the one built by the Viscose Company at Parkersburg, W. Va.

The plant at Parkersburg is on a tract of ground having an area of about 125 acres and located along the Little Kanawha River.

The buildings include the main manufacturing group which is principally of one-story, saw-tooth type, together with auxiliary buildings, also power and boiler houses, reservoir and filtration plant as also a large dining hall for the use of employees. The buildings have brick walls with brick on edge sills and stone coping. Roof construction is of steel trusses using the "super-span" saw-tooth design with plank roof and asphalt to suit the various conditions. A 100,000-gallon steel water tank on a steel tower is installed in order to serve a complete sprinkler system. A brick chimney 200 feet high, 20 feet inside measurements is also built.

Complete systems of plumbing and drainage, steam heating and power piping, electric light, power wiring and water purification have been installed, as also have six freight elevators.

In this chapter it has been the author's purpose to show a series of views of different Rayon producing plants in order to give a more rounded out conception as to the type of buildings needed in Rayon production. It can readily be seen that a Rayon plant properly constructed, cannot be ventured into lightly for it calls for a large outlay of capital and proper engineering technique and ability.

CHAPTER XVII

PROCESSING

WEAVING AND KNITTING—GLOSSARY OF RAYON FABRICS— DYEING

RAYON yarn is purchased from the producers mainly as skeins, either dyed or in their natural color. Before processing, however, other operations are necessary which differ somewhat depending on the particular process to which the yarn is to be subjected. Some producers will wind, twist and spool the yarn, thus enabling them to supply weavers and knitters with Rayon in the state required by them for immediate use. There are also intermediate processors who take Rayon yarn from the producer and perform the preparatory operations for weavers and knitters in much the same way the throwster functions in the silk industry.



FIG. 154. Rayon Skeins.

Rayon, like silk, stretches considerably, but unlike silk, its reaction is relatively small, so that excessive or irregular tension reduces the diameter of the yarn at intervals, causing light streaks. On this account the least number of handlings and rewindings is recommended.

The processing of Rayon may be divided under two general headings:

- (1) Woven goods,
- (2) Knitted goods.

The preparation of the yarn for these processes requires somewhat different treatment. In the case of weaving there are both the warp and weft threads to be considered and different preparations are necessary for each of them. The warp threads require a surface treatment to protect them from the constant friction to which they are subjected. This treatment is called sizing. Yarns for knitting need lubricating and therefore a treatment called oiling is necessary.

We shall now consider the first of the two general headings under which processing may be tabulated as stated above.

WOVEN GOODS

Before the actual operation of weaving, it will be necessary to consider the preliminary or preparatory operations which are essential to prepare the yarn for weaving. These may be divided under the headings: (a) winding, (b) sizing.

(a) *Winding*.—When the individual filaments of a Rayon thread are spun together they receive a twist of from two and a half to three turns per inch only, and being of a smooth, elastic and delicate character, they lie side by side quite loosely without any cohesion to bind them together and give them strength to resist the various stresses to which they are afterwards subjected. The worst of these are uneven and excessive tensile strain and the friction of rough surfaces.

The breaking of a single filament is liable to cause bunching and finally the breaking of the entire thread. If not noticed in the various stages of production, such ruptures are almost sure to show up in the winding or weaving operations or else to show as a defect in the finished cloth.

In view of the above, it is essential when winding Rayon yarn from any source whatever and on any type of winding machine to thoroughly observe the following precautions:

(1) *Elimination of friction.*—The elimination of friction and sharp turns is most important in the winding operation. The yarn should never be allowed to come in contact with rough or stationary surfaces. Whenever it is necessary to change the direction of travel such changes should be effected by means of revolving grooved pulleys of large diameter made of glass, porcelain or other smooth hard surfaced material and the angle of such changes should never be more acute than 90 degrees. The contact of the threads with any rough surfaces whether in winding or on the article on which the yarn is wound is disastrous and must be guarded against most carefully.

(2) *Tension.*—The correct tension to be applied to the thread in winding to produce compactly wound bobbins, spools or pirns is most essential and requires very fine adjustments on winding machines to allow for different denier and strength of threads. Even tension is very necessary or the woven goods will show streakiness or greater luster where the tension is greater. To obtain even tension correct speeds must be maintained and every part must operate smoothly and freely. In the case of pirn or bottle bobbin winding where the diameter varies it is necessary to have adjustment on the winding machines to compensate for these conditions and maintain even tension. Tension should rather be applied to the article from which the thread is being wound by means of a brake rather than to the thread itself and in the case of winding from skeins the skein should be mounted on the swift, concentric with its shaft in order to get proper balance. It is also very important

that the tension on bobbins to be used in the same warp or on pirns for use as the same weft should be wound with equal tension on all such bobbins and pirns, otherwise the uneven tension from the same or different bobbins and pirns will be noticeable in the woven goods. It will be seen therefore that the proper tension of the thread under all conditions is of supreme importance.

(3) *Knots*.—Knots are a necessary evil and must be reduced to a minimum both as to quantity and size. In winding, great care should be exercised in the placing of knots, especially on pirns and tapered bobbins so that they do not interfere with the proper unwinding and become tangled or hooked in the threads.

(4) *Speed of Winding*.—The speed of winding should never be excessive or the quality will suffer because of excessive tension, etc. Winding machines should be equipped for variable speed, to suit denier and strength of thread conditions and also with compensating devices to maintain equal tension on tapered bobbins, pirns, etc.

(5) *Atmospheric Conditions*.—Rayon yarn is highly hygroscopic and very sensitive to variation in temperature, therefore care must be exercised in maintaining humidity and temperature at the best conditions for most satisfactory results. Strong air currents should be prevented because they cause vibration of the threads during winding. High humidity is most objectionable because it causes stretching of the thread. A temperature of 65 degrees Fahr. without much variation at any time is most desirable. From the above then it is seen that a dry, uniformly cool temperature at all times is best for proper winding of Rayon yarns.

The thread for warp is usually wound on flanged bobbins and that for weft on pirns. The winding on to pirns can be done directly from the skein or may first be wound on flanged bobbins and from them to pirns. The former method is more desirable and economical, but because of the matting and tangling of skeins during the dyeing process the double method of winding will continue.

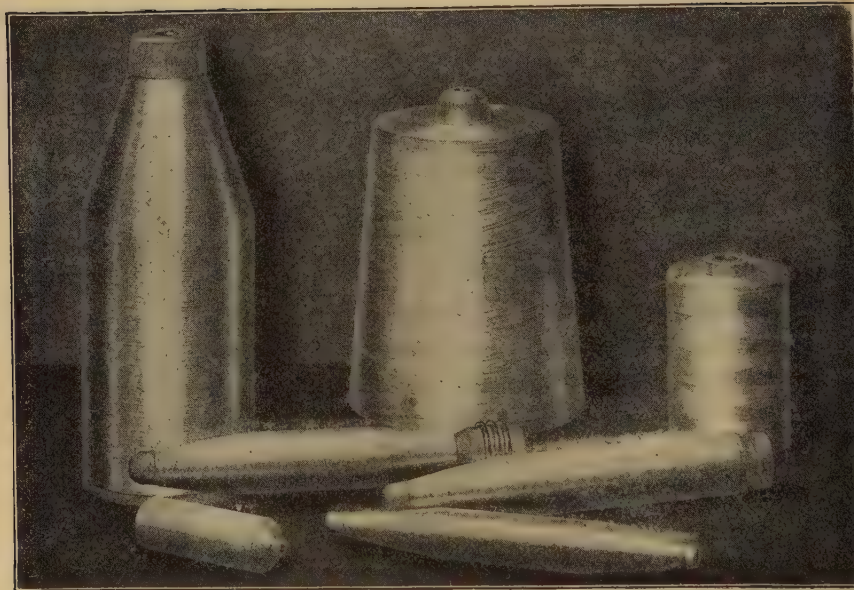


FIG. 155. Bobbins. Rayon Yarns Ready for Use.

The success of the winding operation may be summed up by the following:

- (1) The skill of the operator.
- (2) The quality or denier of the yarn.
- (3) The efficiency of the machine.

As the Rayon industry grows, more skilled operators are being produced and it is well to add here that the problems presented to an operator in the winding of Rayon are very different and more complex than in winding other textiles and an operator skilled in winding other textiles will find himself very much at sea when first attempting the winding of Rayon. Again as the Rayon industry grows, stronger yarns are produced of finer denier which tends to make the winding and subsequent operations less of a problem. Lastly, the manufacturer of winding machines has been forced to build a



FIG. 156. Winding Machine No. 90 for Winding Rayon from Spools onto Bobbins.
(Universal Winding Co., Boston, Mass.)

Rayon winding machine instead of attempting to adopt winding machines for other textiles to the use of Rayon. There-

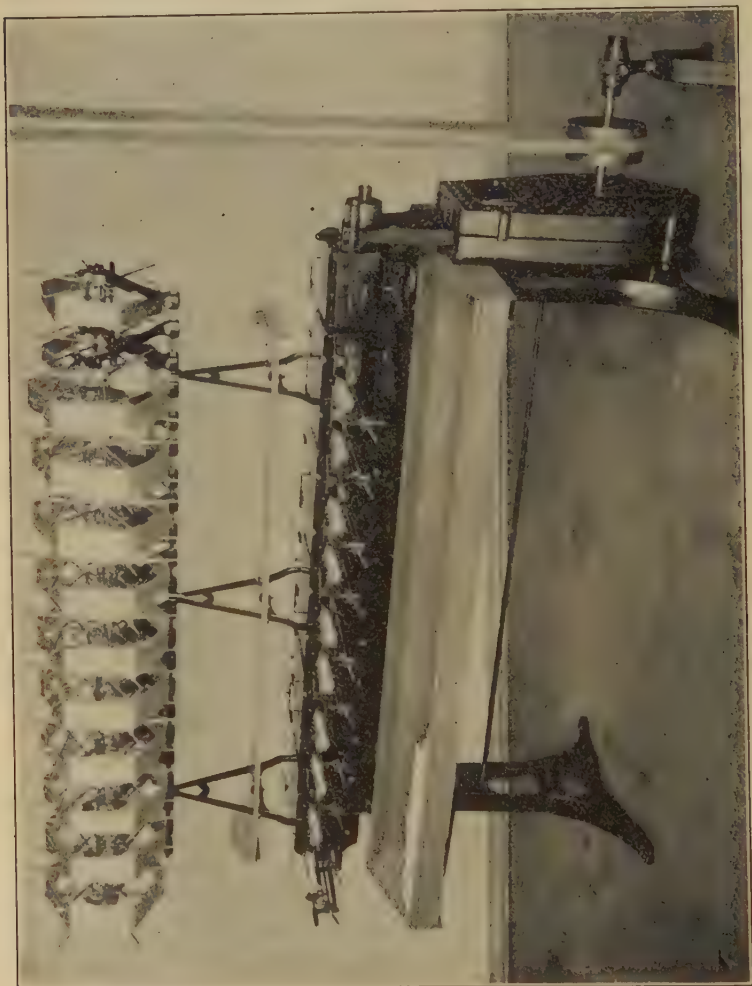


FIG. 157. Winding Machine No. 90 for Winding Rayon directly from Skeins onto Bobbins.
(Universal Winding Machine Co.)

fore, from every angle this difficult operation is being tackled with wisdom and skill and the results are manifested in better goods.

(b) *Sizing*.—Real silk is composed of the fiber proper which forms the core and an outside covering of gum or wax known as sericin, comprising approximately one-fifth of the

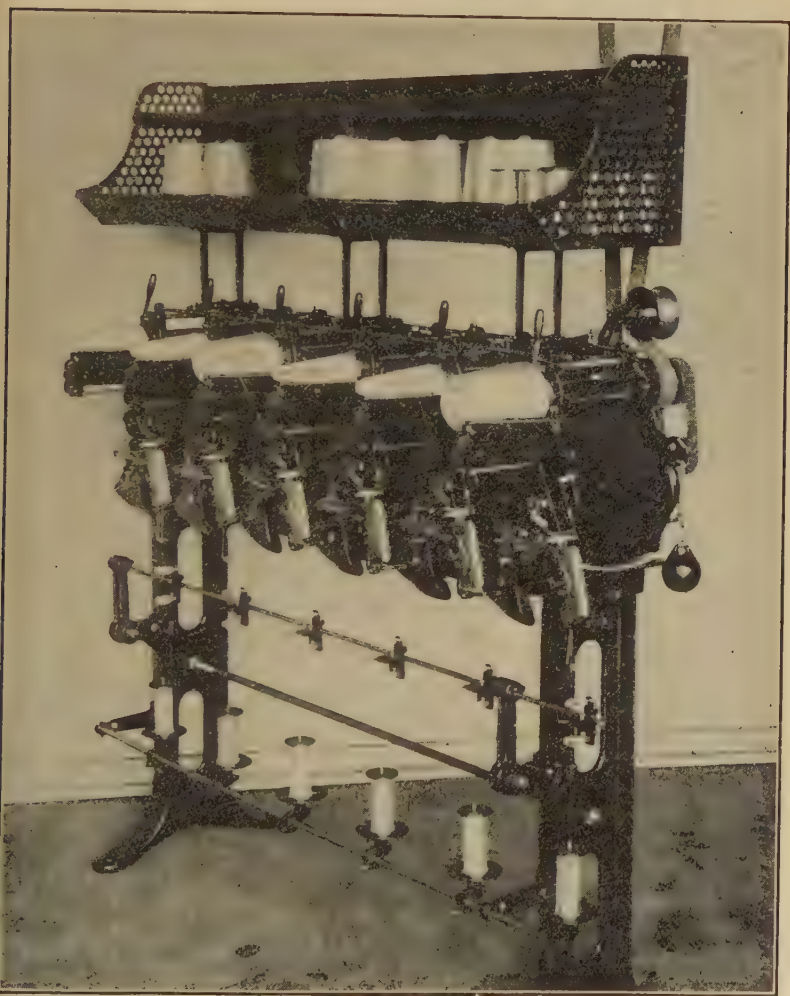


FIG. 158. Winding Machine (No. 50) for Winding Rayon from Spools to Paper Cones for Knitting. (Universal Winding Co., Boston, Mass.)

total structure of the filament. This coating is an integral part of the silk thread and cannot be mechanically removed as by scraping. It presents a surface which is not affected by the constant friction which a warp thread is called upon to withstand in weaving.

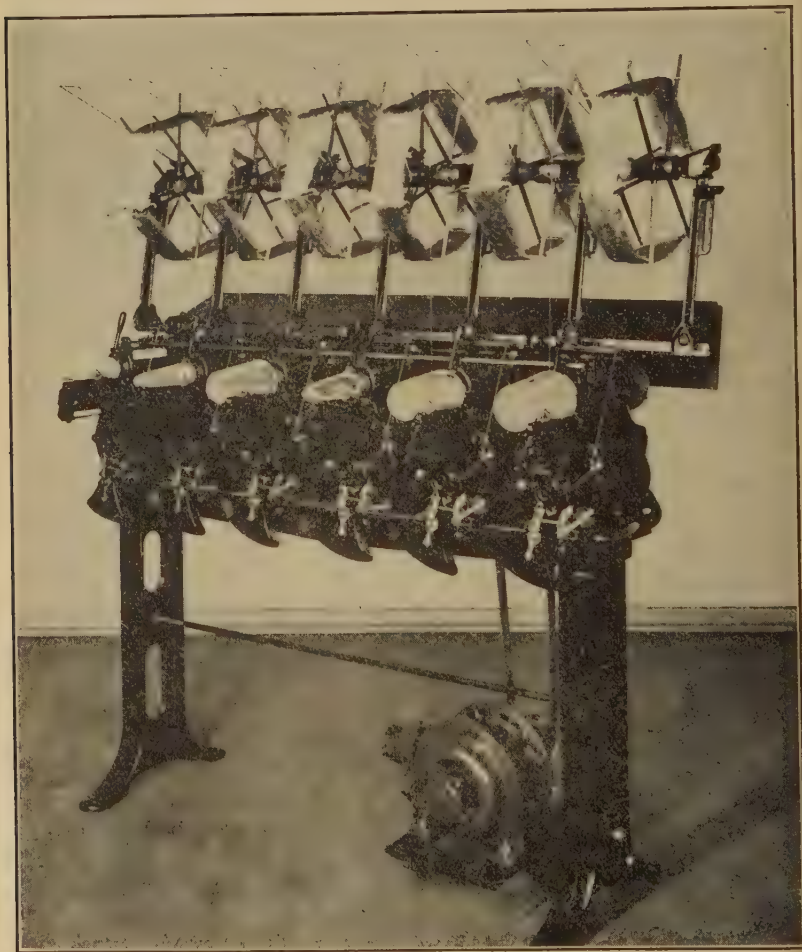


FIG. 159. 50E Winding Machine for winding Rayon from skeins direct to paper cones for Knitting Winding Co., Boston.

Rayon, on the other hand, is composed of the cellulose fiber alone, without any gum or wax covering to protect it, therefore in its ordinary form it cannot be used as the warp thread in weaving. In order to overcome this lack of natural protection, the thread is mechanically coated or sized to duplicate as near as possible the condition of its sister fibre.

In developing a size for Rayon, several very important points have to be considered:

(1) It has to be clear and transparent in order to control the luster or sheen of the fabric.

(2) It must be elastic enough to give with the fiber and not cause cracking.

(3) It must be free from all contaminations and entirely hygienic.

(4) It must be easily applied without damage to the fiber.

(5) It must be easily and economically removed without damage to the fiber and must permit the application of dyes without detrimental effects.

Textile chemists and practical Rayon men are cooperating in their efforts to devise ways and means of improving the sizing itself and the methods of application and removal. There is no one single material yet discovered which can meet all of the requirements, therefore all sizings are combinations of several materials, each of which add somewhat to the requirements and aids the others in offsetting their characteristics which are detrimental. The ordinary gluten and starch combinations used for sizing cotton warp cannot be used successfully for Rayon. The chief ingredients used in size preparations are classified as follows:

(1) Adhesives—starches, gums, glutens, etc.

(2) Softeners—tallow, fats, waxes, soaps, etc.

(3) Antiseptics—zinc chloride, salicylic acids, etc.

In the preparation of these compounds where starch and

gluten are used care must be exercised to offset the effects of fermentation and mildew and on this account antiseptics are added. Caustic soda is also added as a preservative.

Any form of starch or gluten in their ordinary states are unsuitable for sizing as their viscid solution is usually a thick, pasty, sticky mass. In such condition it is impossible to work it on Rayon yarn. In addition, the paste, even in weak solution is quite opaque. A solution of starch when drying tends to contract and Rayon when wet will stretch; therefore it is readily seen that starch alone is not satisfactory. Certain gums, in that they have strong adhesiveness, are transparent and are pliable, but all such materials are only partly satisfactory and it may be generally stated that great improvements can be made in sizing compounds. It will of course be difficult to ever develop a satisfactory sizing for all Rayon yarns, therefore there must always be close cooperation between the Rayon processors and the research laboratory textile chemist.

Sizing is accomplished either by hand, where the skeins or bobbins are suspended in the solutions or on machines where the warp thread in passing from beam to beam is treated with the sizing material, then passed through squeezing rollers and finally over a drying roller. This method is called slashing. In machine sizing care must be exercised not to squeeze the threads too much nor to dry them with too much heat, otherwise trouble will be experienced in weaving. The process of removing sizing before dyeing is called the "boil-off" which consists of boiling the fabric in soapy water and removing all foreign substances, such as oil, dirt and sizing. This process, however, is especially injurious to Rayon yarn.

An interesting development in the sizing of Rayon yarn is described in British patent No. 255909 granted to the Neutrasol Products Corporation of New York.

The "Neutrasol" invention contemplates the application of reinforcing material by the Rayon producer, so that when he

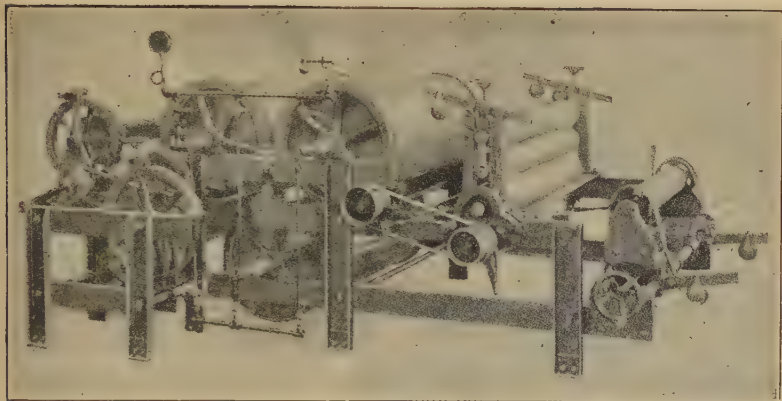


FIG. 160. Ways Sizing Machine No. 81. (Courtesy of Charles B. Johnson.)

delivers the Rayon to the throwster, weaver, or knitter, it will be a completed thread in condition to be worked up at once.

A good sizing or coating for the fiber should add to its strength, should bind the individual fibers of a thread together and prevent opening in the loom or elsewhere, should add to the elasticity of the thread, prevent the development of static electricity, and afford good lubrication to promote the free movement of the thread when traveling in contact with parts of the machine by which it is being converted into a fabric; it should furthermore be capable of easy removal from the fabric after its function is fulfilled, without injury to the fibre. Such a coating should also be proof against changes of climate or temperature, and from varying atmospheric moisture conditions, or mere lapse of time.

To these ends the material proposed in the invention for coating the fibre consists of a compound of waxes, one of which is beeswax, this compound being treated in a manner to render it soluble in water of certain temperature, and to which is added a small quantity of oil. As a concrete formula which will serve the purpose very well, the following is cited:

3 parts of beeswax, $3\frac{1}{2}$ parts of Japan wax, $3\frac{1}{2}$ parts of stearic acid, and part oleic acid or red oil. These materials are placed in a melting pot and reduced to fluidity by heat, whereupon they are thoroughly agitated until most finely and intimately mixed. Then 1 part of commercial dry caustic soda is dissolved in 20 parts of water, and this solution thoroughly mixed with the wax and oil compound. This causes the complete saponification of the Japan wax, stearic acid, and oil, and the partial, if not complete, saponification of the beeswax. On allowing the mass to cool, it becomes solid, in which condition it remains until wanted for use.

The mode of application to the Rayon thread is first to reduce the solid material to fluid form by heat. This requires a temperature of approximately 100 degrees Fahr. above ordinary room temperature, but the actual working temperature of the material is dependent somewhat upon the thickness of the coating it is desired to deposit on the thread. The hotter the material the thinner it is, and consequently the thinner will be the deposited coating. The material after melting may be used full strength, or it may be diluted with water further to control the thickness of the deposited coating. The essential characteristic of the material is, however, that its melting temperature, or the temperature at which it is applied to the Rayon fiber, is considerably above ordinary room temperature; so that when applied in liquid form in a thin film to the thread, the contrast in temperature, when immediately thereafter exposed to room or specially provided low temperature, will be sufficient to cause the immediate solidifying or setting of the film on the thread. The congealing is so rapid, in fact, that when it is applied to a thread while running upwards of 1500 feet per minute, the thread can be wound directly upon a reel located a few inches only from the point of application of the material to the thread, without any stickiness or adhesion of adjoining threads in the finished treated skein on the reel.

This feature renders the material commercially practicable for the producer of Rayon, because he can make the coating process a part of, or a continuation of, the process of manufacturing the cellulose into fiber and thread, which involves a lineal movement of the fibres and thread at a very high speed from the moment the paste is exuded from the dies. The coating material can obviously be applied to the Rayon as an independent process at any time after the yarn has been made, either by the producer of the yarn or by the manufacturer of the yarn into fabric. The mechanical means for applying the material to the linearly running thread is not an essential part of the invention, since any known device such as a roller rotating partially submerged in a body of the hot material may be utilized by leading the thread across and in contact with the roller, and thence immediately to a reel upon which it is wound as a finished thread. If it were necessary to move the thread slowly in its passage from the applying devices to the reel, or to allow the thread to travel a long distance before winding it upon the reel in order to give the applied film time to solidify or "set" before it was wound up, the commercial practicability of the treatment would be much lessened. This is one of the objections to the sizings heretofore used.

Among the ingredients of this coating material the beeswax is the most important, for it not only affords the characteristics of a good coating, as heretofore enumerated, but it prevents the coating from being affected by changes of temperature and moisture conditions, so that it will not experience physical change in any climate or locality before the silk is used. For instance, a moist atmosphere will not make the coating soft and sticky, because water has no effect on beeswax; nor will the highest temperature of the torrid zone soften the sizing, because heat below approximately 150 degrees Fahr. has no effect on beeswax. The quantity of beeswax in the compound is or should be sufficient to prevent the coating as

a whole from yielding to any moisture or heat conditions which it would ordinarily encounter, notwithstanding that the other waxes alone might not be immune from their attack. Japan wax, among other things, is used to furnish a certain amount of stickiness to bind the fibers of a thread together, and stearic acid affords and imparts elasticity to the treated thread, while the oil ensures no brittleness of the coating at any time. A characteristic of this compound is that when in its hot fluid condition it is very penetrative and sticky, so that at the moment it touches the thread in this condition it enters the pores of the fibers and into the interstices of the thread, and upon immediately solidifying thereafter, it becomes firmly anchored to the thread and presents a firm, non-sticky, and smooth surface coating thereon.

The objection to the use of beeswax ordinarily as a coating for silk is that it cannot be completely removed from the thread by any practical means after it has served its purpose as a fibre coating. Beeswax is not sufficiently saponifiable to be wholly dissolved by any ordinary agent, but the invention provides for the intimate association of the beeswax with other waxes or materials which are easily saponifiable and are in a saponified condition by reason of the action thereupon of the caustic soda, so that upon subjecting the treated thread to a hot water bath the coating is converted into an emulsion in which the fine particles of beeswax are suspended, the bulk of the emulsion being taken from the silk or fiber by the water, and the remainder being carried away by one or more subsequent rinsings. This operation is most effectively and rapidly performed in water at 160 degrees Fahr. or over. The naked fiber is thus left clean for dyeing without the necessity for any injurious treatment, such as hard boiling.

The material described is not a mere sizing of the character commonly used to fortify Rayon yarn, such as starch, gelatin, glues, and so forth, which are sensitive to

moisture and weather conditions, and thus lose their efficiency, but is probably as near a synthetic sericin as can be produced, judging by its functions and performance. Natural sericin cannot be mechanically removed from the fiber, as by scraping the yarn with the finger nail or across the edge of a knife, and this is true also of the coating which is the subject of this application; whereas any of the ordinary sizings can be easily scraped from the thread, and are not in any sense an integral part of the thread or fiber. Therefore, when the naked cellulose Rayon thread is provided with a coating of the material described it becomes a perfected and complete Rayon thread corresponding in structure to that of raw silk, and with the fibers effectively strengthened to resist abrasion.

From the description of the patent given in detail above, it will be seen that even now the results of the concerted efforts on the part of those interested is beginning to bear fruit.

While it is not necessary to size Rayon weft threads it is most desirable that they be properly lubricated with special oils which have no bad effect on the yarn and are easily and economically removed. The matter of lubricating Rayon yarn is discussed more fully under the heading of "Oiling"—a preparatory process of Rayon knitting.

Weaving.—It was of course only natural that many problems would arise in the weaving of an entirely new fiber such as Rayon because of its peculiar characteristics which are so different from any of the other textile fibres, the weaving problems of which have been practically all solved and the operations reduced to mechanical standardization.

Broadly speaking, however, the same general operations and routine are followed in weaving Rayon as in silk or cotton. In fact either silk or cotton looms slightly modified may be used for the newer and more delicate fiber.

As a preliminary to weaving, the yarn for both warp and

weft must be properly treated and prepared. Rayon yarn until recent times could not be used as the warp thread in weaving because of its weakness and inability to withstand the friction and tension to which it was subjected as such and cotton, silk or other yarns were used exclusively as warp. Today, however, with the development of proper twisting, winding, sizing, beaming and warping machines these earlier difficulties have been overcome and Rayon is used exclusively as both warp and weft in many different kinds of woven goods.

In preparing the Rayon warp thread it is absolutely necessary to eliminate friction and maintain even tension throughout; also to perform all operations under as uniform temperature and humidity conditions as possible. The winding and sizing of Rayon yarns has been discussed previously in this chapter and similar conditions as were described under winding are necessary in beaming and warping. The sizing operation when mechanically performed can be accomplished during beaming where it is over the sizing roller, then over the drying roller onto the beam. An ordinary warping mill can be used with slight modification, but machines designed specially for Rayon yarn are the most efficient.

In preparing the weft yarn it is most desirable to wind it first from skeins to bobbins at slow speeds and then from the bobbins to pirns at high speeds. It is also most desirable to have the threads properly oiled or lubricated to reduce friction.

When more than one kind of Rayon yarn is to be woven into a fabric it is most essential to see that it is not mixed in any way with the others in order that the jacquard or design be properly carried out after dyeing the fabric, the reason being that different dyes affect the various kinds of Rayon differently and should the Rayons become mixed the result would be chaotic.

While almost any kind of loom can be adapted to weave Rayon with more or less modifications, it is a great deal more satisfactory to have looms designed especially for it because greater rigidity is desirable in order to lessen or prevent vibration.

With the introduction of Rayon, numerous textile manufacturers, especially those who had formerly woven only cotton yarns, found difficulty in the weaving of Rayon because

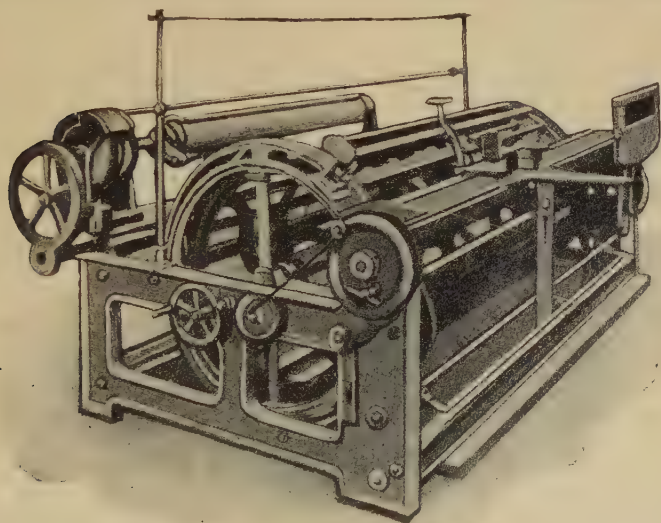


FIG. 161. Warping and Beaming Machine.

of the fact that Rayon does not have the elasticity of either cotton, silk or wool and for the further reason that when Rayon yarn breaks in the weaving operation, the broken ends have a tendency to flare out, thus entangling other yarns in the warp and causing additional breakage. They have also encountered a certain amount of difficulty due to the fact that Rayon is more wiry in its nature than most of the other yarns and, therefore, does not feed off the bobbin in the shuttle with

the same uniformity as do other yarns, unless it is properly controlled.

Recently the author made a thorough inspection of a new type loom which seems destined to correct the difficulties encountered in the weaving of Rayon, in that it has a very much easier action on both the warp and filler yarns, thereby eliminating undue stress and wear on the yarns so that breakages are reduced to a minimum. This machine is owned by the Lucas-Lamborn Loom Corporation of New York City.

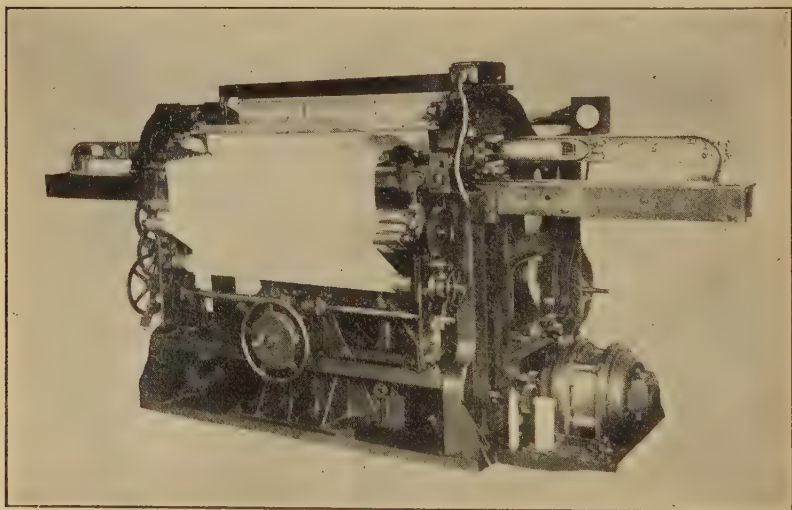


FIG. 162. The Lucas-Lamborn Rayon weaving loom.

Numerous tests have been conducted on this loom on all kinds of plain fabrics, including silk, Rayon, cotton, linen, wool, asbestos and wire screening. These tests proved that breakages in warp and filler yarns were almost entirely eliminated and the fabrics woven were of a very uniform weave, all fabrics from silk and Rayon to wire screening being woven satisfactorily upon the same machine without any change in its fundamental construction.

Practically all machines used in the making of fabric to-day except looms have been perfected so that they represent the modern trend of the manufacturer toward the use of precision machinery. The loom, however, has remained much the same as it was fifty years ago except for the addition of certain accessories such as the magazine, the box, the jacquard and the stop motions. This new loom, however, is constructed almost entirely of high-grade metal with all straps, picker-sticks, springs and wooden parts eliminated.

KNITTED GOODS

The preparatory steps or processes necessary in the consideration of the second division of the processing of Rayon may be tabulated as: (a) winding, (b) oiling.

(a) *Winding*.—The same winding operation is necessary in the preparation of Rayon yarn for knitting as for weaving and the same care and attention must be exercised in carrying out this operation. The yarn is wound from skeins either directly to bottle bobbins or first to flanged bobbins at slow speed and then to the bottle bobbins at high speed. A repetition of the chief points to remember during this operation will be in order because of their importance:

(1) Even and proper tension throughout all operations, including compensating devices on winding machines to allow for bottle bobbins.

(2) Elimination or minimizing of friction by guarding against rough edges and sharp turns and the use of proper media when changes in direction of travel are necessary.

(b) *Oiling*.—Rayon yarn, because of its tendency towards stiffness or wiriness must first be subjected to some form of lubrication or treatment for softening before it can be successfully used on modern, high-speed knitting machines. Oil as a softening agent as well as a lubricant is an important factor in knitting Rayon and is almost universally used for

that purpose. It penetrates the cellulose structure of the fibre, thus keeping out water which lowers its tensile strength; it affords internal lubrication between individual filaments and fibres acting as a protecting film against rubbing together of such filaments and fibres; it makes the yarn pliable and more easily workable through the knitting machines and it lubricates the needles.

In using oil for softening Rayon yarn, certain very important factors must be considered:

- (1) Its suitability.
- (2) Its cost.
- (3) Its removability.

1. In considering the suitability of the oil, it is very short-sighted policy to allow the price to be the primal factor. The first consideration is to get the best lubricant obtainable for the particular yarn and the best obtainable in this case is not necessarily the one which costs the most. There are so many factors entering into the manufacture of Rayon yarn and its characteristics differ so with different processes that the proper kind of oil to use is a question for the research laboratory and chemist to decide.

2. The cost of softening and lubricating Rayon yarn is naturally an important one and can be controlled only by: (a) a careful study of the actual conditions of the yarn and factory, (b) the method of application and (c) the quantity used.

(a) A knowledge of all conditions is necessary for the research laboratory or chemist to prescribe intelligently the correct oil or combination of ingredients to soften and lubricate the yarn and at the same time permit of quick and economical removal of it. Oils which discolor or leave unpleasant odors should not be used and the particular oil should be easily removed in finishing. It is very important that the oils contain no free sulphur for it is not removed in the wash off and even a trace of sulphur causes streaks in the finished material besides giving trouble in dyeing.

(b) The application of oil to Rayon yarn is accomplished, generally speaking, in two ways; one is to run the yarn as it comes from the skein over a drum turning in the oil, usually in the opposite direction to the travel of the yarn. In some cases the drum is replaced by pieces of felt dipping into an oil bath and sucking the oil up as in the case of a lamp-wick. In the second method, the skeins are soaked in a bath of oil, then placed in a centrifugal machine to remove the excess oil.

(c) The quantity of oil used by various manufacturers of Rayon yarn and knitted goods varied so, and the cost of oil being such an important factor in the ultimate cost of finished goods, the Department of Commerce carried on an investigation based on the standard practice then in operation in the hosiery industry in order to establish a standard maximum percentage of oil for use on Rayon. The report submitted by the Department concludes by establishing this maximum figure as 6 per cent based on the weight of the conditioned yarn.

3. *Removability*.—The oils used for Rayon yarn are either compounded oils or soluble oils. Compounded oils are mineral and vegetable oils mixed at the right temperature. These oils, which of themselves are only partially emulsifiable with water require the addition of an alkali such as borax, soda ash or potash. The chemical reaction of such a mixture is to form a soap which is known as an emulsifier which can be removed in the wash off. In soluble oils the emulsifier is present in the oils themselves, and, therefore, need no further mixing to aid their removal in the wash off.

Oiling of Rayon for knitting makes the whole process much easier besides reducing the number of press-offs through broken filaments. For the same reasons as explained above, oiling of the weft threads in weaving is also absolutely necessary so that the process of oiling is a boon and a blessing to the processors of Rayon.

Knitting.—The knitting of goods with Rayon yarn is

accomplished on multiple high-speed circular knitting machines almost universally, and as the ordinary denier of the yarn is 150 with the demand constantly for finer denier, it can be realized that this process presents many problems which have been and are being met by the knitting industry and manufacturers of knitting machines with unsurpassed patience and zeal. It is of course of primary importance that the preparatory steps such as winding and oiling be properly taken care of, also all bottle bobbins must be in perfect condition, free from roughness and other defects which tend to damage the yarn in any way. It is also necessary to see that all parts of the knitting machines and equipment are in perfect conditions, well lubricated, easy running and spotlessly clean. There should be no sharp turns or changes in direction of the yarn and all pulleys should be of large diameter and of smooth, hard material. The speed of knitting machines should be constant and the tension on the yarn even at all times.

The question of cleanliness in operators, machines and surroundings is one that cannot be too strongly impressed on all concerned and operators should be chosen who are particular of their personal cleanliness and in other habits. Some of the largest knitting companies employ manicurists for the operators because a broken or rough finger nail can do a tremendous amount of damage.

Temperature and humidity conditions are very important in knitting mills where Rayon yarn is used. The temperature must be constant and humidity low. Air currents and draughts from any source must be guarded against and excessive vibration is extremely dangerous to the production of the finest knitted fabrics.

The importance of making the least number of knots in the yarn cannot be over-emphasized and when knots do have to be made it is very necessary to see that they are properly tied so that they will not slip and open up when the fabric

is used or dyed, and that they will properly pass the needles and guides. In this connection, it should always be remembered that when knitted material is inspected the pickers should not slip the knots too close, else there is the danger of them slipping open and causing holes in the material. When

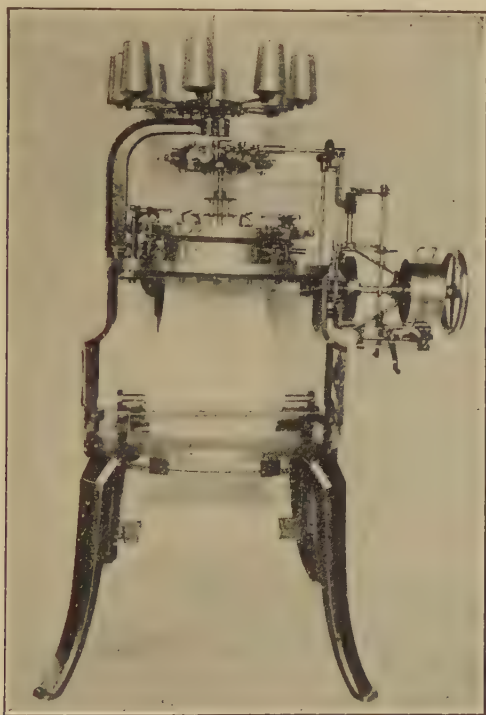


FIG. 162A. Spring Needle Knitter for Underwear and Dress Goods
("F. B. S. S." Challenger).

hanks have to be made the weaver's knot is to be preferred; some use the reef knot or the fisherman's knot, but the former has the disadvantage of slipping occasionally and the latter, being larger, has the tendency to catch. In all cases knots should be tied as tightly, trimmed as closely, as possible and

still not slip. When holes do occur in knitted fabrics they are carefully darned. In some inspection departments all knotted places are darned to prevent the possible occurrence of holes.

Rayon yarn has invaded almost every branch of the knitted goods industry and is being used in large quantities in hosiery, outerwear and women's underwear, but while some men's underwear is made of Rayon it has not become generally popular or fashionable, therefore, the demand for it is not, comparatively speaking, very great.

In the hosiery division Rayon is used alone or in combination with silk, cotton or wool. Chart 22 gives the comparison of hosiery production in the United States for the last six months of 1926 and 1927. It also gives the proportion of pure Rayon in comparison with the mixtures.

In 1915 approximately 65 per cent of the domestic production of Rayon went into the hosiery industry. This amounted to about 3,000,000 pounds. In 1927, about 23 per cent only of the domestic production was similarly used, but this amount was approximately 17,000,000 pounds or nearly 600 per cent in twelve years.

In the case of mixtures of Rayon yarn with other fibers the Rayon is usually put on the outside because a better appearance results. Another method is to twist the different yarns before knitting. The tremendous demand for fancy sport hosiery has extended the use of Rayon in this direction for with it can be produced the heather color effects in almost unlimited variety by means of cross-dyeing.

The universal use of Rayon or Rayon mixture stockings by girls and women has brought about a degree of specialization which few people realize. Nearly all Rayon stockings are manufactured on high-speed automatic circular machines in factories devoted exclusively to this branch of the industry

and often equipped to use Rayon yarn alone without the admixture of any other fibre. The Rayon is knitted into long tubes like the links of sausages, each link or length being an almost completely finished stocking, requiring only the joining up of the toe and linking the welt. The stockings are then dyed, usually by those specializing in this operation, and returned to the manufacturer for inspection and packing. The sale or distribution of the finished hose is also specialized to a great degree as to quality and price.

Competition is so keen in the hosiery industry that manufacturers are continuously studying the problem of cost of production. Most manufacturers wind their own yarns from the hanks onto bottle bobbins and they have carried on considerable research work relative to the process of oiling the yarn before knitting. The use of bobbins of large diameters permits the operators to devote more of their time and attention to the proper functioning of the machines. Rayon press-offs, a source of waste in the hosiery industry, need not be sold for waste as heretofore because with machines this material can be rewound at very small cost. The installation, by manufacturers, of their own dyeing plants is a further aid in reducing cost of production.

There have been developed many knitted garments for outerwear which are in demand especially on account of the artistic and decorative effects which can be produced by mixing various Rayon yarns with wool and cotton and, by dyeing the various fibres different colors many beautiful and artistic effects are obtained. One of the first knitted fabrics, which is now a staple, is "tricollette."

It is now possible to make knitted fabrics of such fine gauge, suppleness, softness and smoothness that it is difficult to distinguish them from loom woven fabrics. Knitted Rayon fabrics were at first employed for sportswear only, because of the brightness of colors which could be obtained but now

that the luster has been dulled they can be applied in many ways, such as frocks, suits, overblouses, sweaters, "slip-ons," jacquettes, etc.

Less than ten years ago, knitted Rayon fabrics were not used for underwear in the United States, but in 1927 about one-third of the total domestic production of Rayon was used in the underwear industry and within the last two years the men's underwear industry has been invaded. It is in this industry that Rayon probably makes its greatest appeal for who does not desire to have undergarments of beautiful, soft, smooth, silklike texture, instead of the coarser and more plebeian cotton goods.

Not only are the appearance and feel of Rayon goods for underwear in their favor but they now stand up under the wearing and laundering as well as cotton and they maintain their color and do not shrink.

Distribution of the domestic Rayon output for 1927 among the various textile industries was about as follows:

Underwear	33
Hosiery	23
Cotton goods	20
Silk goods	13
Knitted goods, miscellaneous	3
Braids	2
Woolen goods	1
Unclassified	5
TOTAL	100

B: GLOSSARY OF RAYON FABRICS

By Alexis Sommaripa, Manager of Business Research, Du Pont Rayon Company.

In every fabric woven on a loom there are two systems of yarn, one running parallel with the selvage, that is, length-

wise, called the warp and the other running cross-wise in the fabric binding the warp threads together, designated as filling. The two form different weaves according to the manner of their interlacing. The warp lies in parallel lines in the loom and certain parts of it are alternately raised and depressed at every pick, allowing the shuttle to pass through them with the filling.

Either the warp or the filling or both can consist entirely of Rayon. The warp of a fabric can be partly composed of Rayon, the other thread consisting of cotton, wool, silk, etc. This is usually accomplished by the use of a double system of warp yarn or by twisting the different yarns together. The filling, likewise, can consist of different kinds of yarn twisted together or used on the so-called box loom, which contains several separate shuttles and allows the interjection of different yarns at various picks.

Rayon is used in a great variety of weaves, ranging from the simplest to the most complex and elaborated ones. We will briefly discuss the basic weave as well as the few fancy constructions. We will elaborate later when describing various Rayon fabrics.

The simplest possible system of warp and filling crossings takes place in the plain weave. In it each end of warp goes alternately over and under the successive picks of filling and each alternate pick of filling goes over and under the same warp thread.

The basquet weave is a variation of the plain weave produced by two or more warp ends passing alternately over and under a corresponding number of filling ends. A ribbed or corded plain weave is produced by the regular alternate interlacing of an unequal number of warp and weft ends or of warp and weft ends of materially different sizes.

In the twill weave the threads are raised over or pressed under more than one thread. For this purpose at least 3

threads are needed which form a repeat. In the one up and two down twill, for example, the first pick passes over the 3rd, 4th, and 7th, etc., warp threads, the 2nd pick passes under the 1st warp thread and ties in the 2nd, 5th and 8th warp threads and the 3rd pick passes under the first two warp threads and ties in the 3rd, 6th and 9th, etc. Diagonal lines formed by the two weaves can run to the right and to the left across the fabric, the degree of the twill line depending on the number of threads involved, the relative size of the warp and filling and the number of threads of each set of yarn within a given space.

In a satin, within a given repeat the first interlacing of the successive filling thread with the warp comes at irregular points instead of, as in a twill weave, at regular successive points. The purpose is to minimize the points of interjection and by scattering them to create a uniform surface without any obvious twills made up predominantly of either warp thread (warp satin) or filling thread (filling satin). In either type the long floats lie side by side reflecting the light all in one direction, thus creating a smooth, lustered fabric.

All the described weaves, if not made too complicated, can be produced on plain looms where from 2 to 8 harnesses are operated by cams. As mentioned before, to inject a separate, different filling it is necessary to have a loom which has more than one shuttle.

Fancy weaves are created by more complicated or irregular interlacing of warp and filling threads. To produce them it is necessary to have dobby looms which can operate as many as 25 harnesses. Fabrics with different weaves used in different parts of the width of the cloth and in small figured designs can be woven on such looms. Larger or more complicated figures have to be produced on jacquard looms in which all threads are operated separately through a predetermined design.

Special attachments are required to produce such fabrics as the terry weaves, pile fabrics and marquissettes. Pile fabrics such as velvet are produced by the use of multiple beams and rods. Terry fabrics like Eponge are woven with 2 sets of warp, one of which is forming rows of loops, the yarn on it being wound and kept very flat. Leno fabrics are also made with 2 sets of warp but the threads of the latter cross each other in the weave. Fancy effects in the fabric can also be made with the use of specially prepared yarn such as the one twisted with high number of turns or the novelty yarn which is made with loops or knots shown on the surface of the cloth.

A fabric can be woven or knitted either with yarn which has been previously dyed or printed or it can be woven first and bleached, dyed or printed afterwards in the piece. By combining different yarns, for example Rayon with wool or silk or cellulose acetate with other makes of Rayon or with cotton a fabric can be piece-dyed in multi-colored effect.

As mentioned before about 50 per cent of Rayon is consumed in woven fabrics. These are woven either by silk, cotton or woolen mills. We will first discuss the cloth made entirely of Rayon.

FABRICS MADE ENTIRELY OF RAYON

Rayon was originally used only as a decorative medium. A few threads of Rayon in the warp or in the filling produced a rich glittering effect. As recently as five years ago, it was not considered that Rayon had enough strength in it to make a garment entirely of Rayon. Women's knit underwear, however, which is wholly composed of Rayon demonstrated the excellent wearing and washing qualities of fabrics made from this yarn. Rayon voile, which was launched in 1926, clearly indicated that a sheer all-Rayon fabric can be made to be

serviceable. This item, indeed, was remarkably successful, amounting in the spring of 1928 to more than 12 per cent of the wash goods sales of retail stores.

The development of all-Rayon woven fabrics during the last two years is an important landmark in the history of this fiber. Starting as a specialty, it is now used in staple constructions such as sheers, satins, crêpes, and crêpe-back satins. Entirely new fabrics are also created, due to its properties. Some of these clothes will remain as staples for the next few years. The group of Fig. 163 shows the most important all-Rayon constructions, and indicates the type of looms required to produce them, as well as the customary system of dyeing through which they are put.

Taffetas, which are fabrics made by the use of the plain weave are extensively used by the millinery trade for hat-linings, as well as for linings of caskets. By the use of a finer denier, such as a 75 denier both in the warp and in the filling a finer cloth is produced, which is called radium. It is sometimes made even with 45 denier, with about 120 warp ends by 90 picks of filling. Such fabric is well adapted for dress-goods and women's underwear.

The material No. 1 shown in the group of Fig. 163 of fabrics is Rayon taffeta which has been yarn dyed and woven on a box loom. It can be used for women's or children's dresses, scarfs and pajamas.

The most important all-Rayon fabrics are the sheer Rayons and crêpes. The Rayon voiles were the first to be created. They are sheer fabrics weighing approximately one-tenth of a pound per square yard. The main character of this fabric is the openness of the weave. To prevent an open fabric from slipping it can be either woven as a marquissette where the warp thread is interlaced or the threads can be twisted with a high number of turns which gives them somewhat of a corkscrew character, thus holding them and pre-

venting them from slipping. The latter method is used most extensively, 75 denier Rayon being twisted with from 28 to 35 turns per inch. The construction of the voiles range from 64 warp ends and 64 picks of filling per inch to 60 ends by 56 picks. By using an occasional untwisted end and pick among the twisted threads an interesting contrasting effect can be accomplished, as the twist dulls Rayon which the un-

TABLE 90A.—ALL RAYON FABRICS

	Dyeing				Loom			
	Skein	Piece-Dyeing			Plain	Box	Dobby	Jacquard
		Plain	Cross	Printed				
Taffeta, faille check taffeta	✓	✓	✓		✓			
Moiré (ribbed fabric) . . .		✓		✓	✓			✓
Twills: scrap	✓		✓	✓		✓	✓	
Woven-crêpe effects (perognet type)								
Satin ciré		✓	✓	✓			✓	✓
Striped: shirtings, sleeve-linings								
Voile		✓	✓	✓	✓			
Organdie		✓		✓	✓			
Dimity		✓		✓	✓			
Ninon		✓			✓			
Georgette		✓		✓		✓		
Romaine		✓	✓	✓		✓		
Marquissette		✓		✓				
Crêpe-de-chine		✓		✓		✓		
Flat crêpe		✓		✓		✓		
Canton crêpe		✓		✓		✓		
Fancy crêpe	✓	✓	✓	✓		✓	✓	✓
Chine crêpe	✓	✓	✓	✓		✓		
Crêpe satin			✓	✓		✓	✓	
Sport striped Rayon	✓		✓		✓	✓	✓	✓
Faille		✓				✓	✓	

twisted yarn remains shiny. Piece dyed Rayon voiles are used for women's underwear, window curtains and dress goods. Printed voiles are extensively used for dress goods. In Fig. 163 No. 2 shows a printed Rayon voile with a dimity

effect produced by untwisted yarn. Design No. 3 shows a Rayon voile background on which a flower has been woven by means of special swivel loom. Rayon voiles are made of heavier yarns than the ones used in manufacturing of silk voiles or chiffon. They are, therefore, somewhat stiffer and heavier than the silk fabrics. The skirts getting longer, however, and with so much attention to the line and the flaring silhouette materials have to have weight otherwise they will not have any style. There is accordingly a decided feeling for heavier, stiffer, sheer materials which started with the tulle last year and is now going to mousselin and silk organdie. The characteristics of Rayon voiles will therefore add a good fashion note to the spring and summer dresses. Two classic summery cotton fabrics, the organdie and dimity, have also been made with Rayon. To give the fabric sheerness 65 denier has been used but a greater number of ends and picks are employed. This was probably necessary as in order to make the fabric smoother than the voile a smaller number of turns of twist have been used and the closer construction is relied upon to prevent the yarn from slipping. To secure the great crispness required a stiffer yarn with a smaller number of filaments is desirable. These fabrics are more even, smoother and finer than the regular cotton construction. The cotton voile dimities and organdies, however, are an important group of fabrics. A material similar to the above described construction but made softer on account of multi-filament yarns used is utilized now in the manufacturing of women's underwear, being often called Rayon ninon.

To create a pebbly or mottled appearance characteristic of sheer fabrics such as crêpe, georgette or Elizabeth a higher twist than in voiles has to be used. Sheer Rayon fabrics are now made in a construction of 60 ends by 60 picks per inch of 75 denier Rayon with 60/65 turns to the inch. The shrinkage of the yarn due to the higher twist makes these fabrics



FIG. 163. All Rayon Sheers. 1. Rayon Taffeta, Yarn-dyed Woven on Box Loom; 2. Printed Rayon Voile with a Dimity Effect; 3. Rayon Voile Background on which Flower, Woven by Means of a Sp. Swivel Loom; 4. Printed Rayon Georgette; 5. Twill Georgette; 6. All Rayon, Jacquard Sheer Fabric, Cross-dyed.

somewhat heavier than the voiles. Unlike the latter the Rayon georgettes are made in the usual constructions of alternating two threads of right and two threads of reverse twist both in the warp and filling. The higher twist adds additional assurance that the fabric will hold in the seams. The use of the right and the reverse twist makes them less slippery on a sewing table, thus making them easier to handle. A construction of the Romaine type is also produced in which instead of the plain weave used in voiles and georgettes a basquet weave is employed. A printed Rayon georgette is shown in No. 4, Fig. 163, while No. 5 is a twill georgette in which four alternating ends of Acetate and Viscose Rayons have been used with a resulting check produced by cross-dyeing. No. 6 is an all-Rayon, jacquard sheer fabric, which has also been cross-dyed. It is made with Viscose Rayon warp and with one pick of this yarn alternating with a pick of acetate.

The first crêped fabric to appear successfully in this country was the Peroquet crêpe, the beautiful effects of which were not produced by the twist but by an ingenious weave. In No. 1, Fig. 164, an example of this fabric is shown in a check pattern made by the use of dyed yarns.

Rayon flat crêpes have been made in Europe very successfully for the last two years. They are now sold extensively in the United States, dyed in plain colors or printed. No. 2, Fig. 164, is an example of a printed Rayon flat crêpe. As in the case of silk crêpes these fabrics are made with high twist only in the filling. The construction most extensively found in Europe and in this country is 110 ends by 68 picks. Both in the warp and filling 100 denier multi-filament yarn is usually employed. The filling is creped with 50/55 turns alternating 2 picks of right and 2 picks of left. As in the case of the georgette, a box loom is necessary to produce these fabrics. Rayon canton crêpes have also been produced with 110 ends of 100 denier and 48 picks of 200 denier or 70

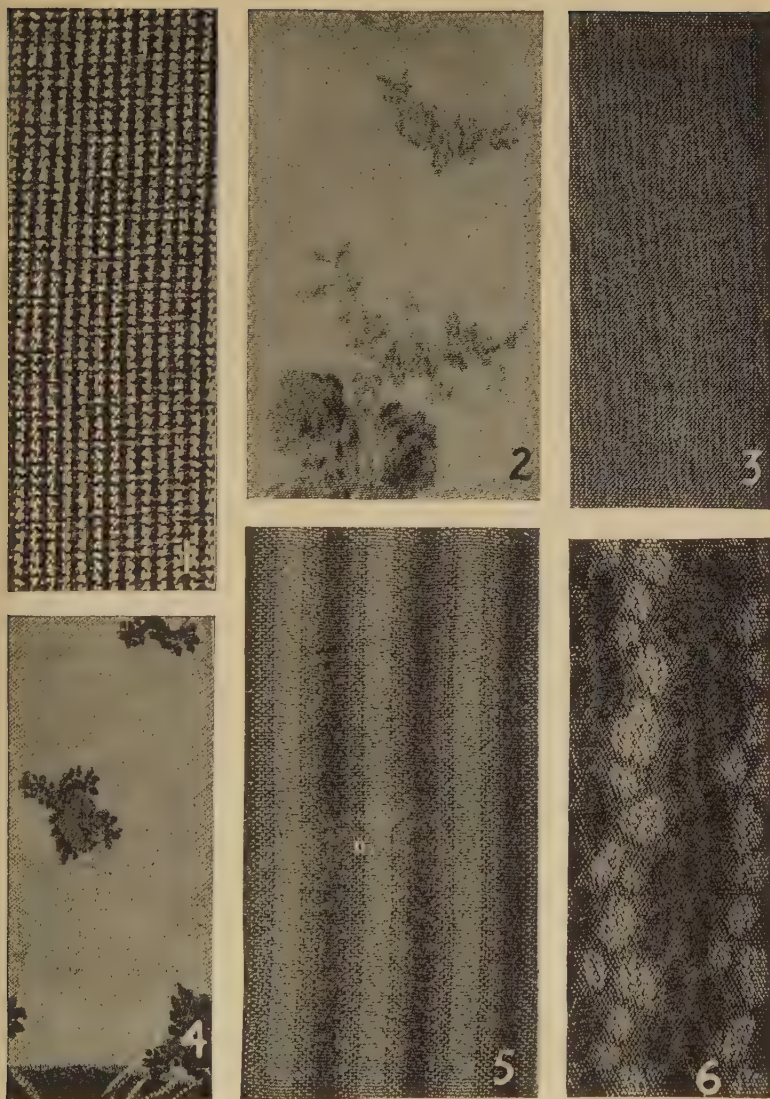


FIG. 164. All Rayon Crêpes. 1. Perroquet Crêpe in Check Pattern; 2. Printed Rayon Flat Crêpe; 3. Flat Crêpe with a Chine Effect; 4. Raised Flower Effect Produced by Swivel Loom; 5. Heavy Rayon Crêpe with Multi-colored, Cravat Design; 6. Heavy Rayon Crêpe with Chevron Pattern.

picks of 150 denier multi-filament yarn. A good usual construction of an all-Rayon crêpe satin is 225 ends and 96 picks of 80 denier multi-filament yarn. All these Rayon fabrics come in direct competition with part silk cloth, the bulk of the weight of which is constituted by metallic salts. Rayon possesses the advantage, however, of being entirely washable.

In Fig. 164 we are giving some examples of fancy Rayon crêpe fabrics. No. 4 has a raised flower pattern woven through the medium of a swivel loom. No. 3 is a flat crêpe with a chiné effect produced by twisting together Viscose and Acetate Rayon threads for the warp and cross-dyeing the fabric. Nos. 4, 5 and 6 are heavy Rayon crêpes with multi-colored effects also produced by cross-dyeing. No. 5 has a cravat design and No. 6 a chevron pattern both of which are very fashionable.

Satins and twills made entirely of Rayon are rapidly supplanting similar fabrics made of a combination of Rayon with cotton. Twills and satins, however, comprising the ones made entirely of Rayon as well as in combination with silk or cotton have shown a steady increase in the sales of the wash goods and silk departments of retail stores, amounting in the spring of this year to about 5 per cent of the total business of each of these departments. In plain shades these fabrics are used for women's slips, lining, negligees and curtains. When printed, they are not only used for the same purposes but also for women's dresses. Figure 165, No. 1, is a cross-dyed chiné satin. No. 2 is an attractive printed dress satin while No. 5 is a cross-dyed brocade. The patterns on Nos. 4 and 5 have been made by the finishing process. No. 4 is a satin which has been embossed while No. 3 is a cellulose-acetate fabric which shows a shiny pattern on a dull surface, the latter having been made by applying heat.

Very attractive Rayon ciré satins can be made through the use of hot rollers applied to an all-Rayon fabric. This effect is permanent if the fabric is made of cellulose acetate. The ciré satins are used for hats, belts, sport-jackets and modern art draperies.

Beautiful moirés are made of fabrics composed either entirely of cellulose acetate or of cellulose-acetate warp and viscose Rayon filling. These fabrics are also put through a special finishing process which gives them a permanent moiré effect. They are used in different weights for dresses, linings, upholstery and draperies.

In Fig. 166 we are showing a variety of fabrics. No. 4 is an all-Rayon French faille, a fabric very popular in Paris at this time. No. 2 is a net, 90 per cent of which is Rayon. It is used for dresses, hats and interior decoration. No. 1 is a lining for sleeves of men's suits. No. 3 is a shirting. No. 5 is a fancy crêpe.

RAYON AND SILK FABRICS

From a production standpoint Rayon, warp-silk filled twills and satins and heavy radiums are probably the most important. As mentioned before, these fabrics have a variety of uses. The silk warp-Rayon filled taffeta used for hats and casket linings is also a big item.

From the point of view of prestige and beauty, however, the novelty fabrics are most important. In Fig. 167 are shown a few representative fabrics of this class. No. 1 is a matté alpaca. No. 2 is alpaca with a jacquard design. No. 3 is a jacquard satin. No. 4 is a beautiful cross-dyed fabric. No. 5 is a printed, heavy Surah. No. 6 shows an interesting jacquard design in which a raised bright Rayon pattern contrasts with a dull background of silk. To create most high-grade

novelty Rayons it is usually necessary to take advantage of multi-filament yarns.

Fine denier and fine filament Rayons, indeed, are responsible for the beauty of transparent velvet. It was generally thought that the use of silk in the pile of the latter would not allow the fabric to be as transparent as is possible with Rayon. The high sheen and the softness of the latter gave this fabric an enviable popularity.

In Fig. 168, No. 1, is shown a printed transparent velvet. In No. 2 a cut, cross-dyed velvet, in No. 3 a fabric in which the pattern has been accomplished by crushing and in No. 4 showing the famous Afghan, which carried Paris by storm. Its surface is less brilliant but has a peculiar hammered appearance which is exceedingly beautiful. It is even more open than transparent velvet but has wonderful wearing qualities as its pile does not crush easily.

RAYON AND WOOL MIXTURES

The fabric made of Rayon and wool form two distinct groups, one where the entire warp is made of Rayon and the filling is wool and the other where Rayon is used as part of the warp or filling. The former is produced by silk mills in weaves such as rep, ottoman, armure, etc., which previously used to be made from silk and wool. In Fig. 169 we are showing examples of such fabrics which we will discuss further.

The Rayon warp gives the fabric lightness, softness and its delicate sheen while the wool gives it excellent draping qualities and somewhat of a roughness and ruggedness characteristic of the modern spirit.

Flaminga crêpes and the Dragon satin, two Bianchini creations, have been most successful in Europe and in this country. Both of these fabrics have creped wool filling which gives



FIG. 165. All Rayon Satins and Twills. 1. Cross-dyed Chine Satin; 2. Printed Dress Satin; 3. Cellulose Acetate Fabric with Lining Pattern on Dull Surface; 4. An Embossed Satin; 5. Cross-dyed Brocade.

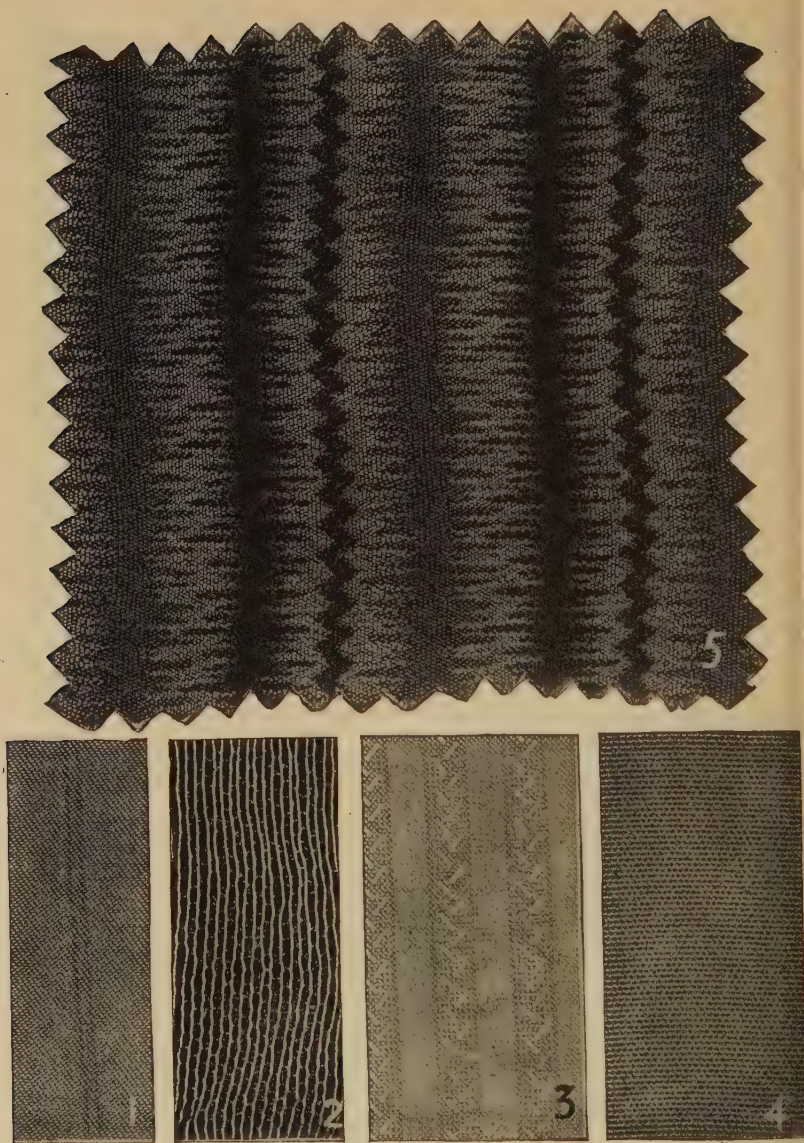


FIG. 166. All Rayon Fabrics—Miscellaneous. 1. Lining for Sleeves of Men's Suits; 2. Net, 90 Per Cent of which is Rayon; 2. Shirting; 4. All Rayon French Faille; 5. Fancy Crêpe.

them a pebbly surface. It is very likely that the extensive use of the Flaminga type fabric for women's dresses in Europe started the popularity of heavy marocain crêpes in this country. The Flaminga type is used in plain colors or in printed designs. In this country it is also made with woven effect such as shown in No. 4, Fig. 169. The satin is primarily used in black for women's coats, although it is very effective in bright colors for evening wraps. A lighter weight crêpe is shown in No. 6. This fabric has a three-color effect created by cross-dyeing the warp as well as a print. Another cross-dyed fabric is the No. 1 and No. 2, the former having somewhat of an Alpaca appearance while the latter is heavy faille. Rayon and wool printed crêpe satin is shown in No. 3, while Rayon warp-wool filled rep are found in attractive jacquard designs such as No. 5. A great variety of armure design is used for women's coats in the manufacture of which are also found Bedford cord, made of the combination of the two fibres under consideration. To create all the above-described fabrics it is almost always necessary to use multi-filament yarn for the purpose of obtaining softness, covering power and subdued luster. 100 denier and finer yarn are usually employed in these fabrics.

The Rayon and wool fabrics woven by woolen mills can be roughly divided into three groups, the cheaper, cotton and wool men's wear items in which Rayon is used to brighten the otherwise uninteresting surface, the cheaper women's wear item where it gives the cloth a glittering effect and the higher end of fabric for women's dresses and coats. In the latter fabric Rayon is used in woven patterns as motif decoration as a solid usually frosted effect or to create a flake or knob or plain surface. In all cases Rayon is used very discreetly. It is scarcely discernible (detectable) but there is always an unmistakable glint and fresh appeal about the fabric which Rayon brings.

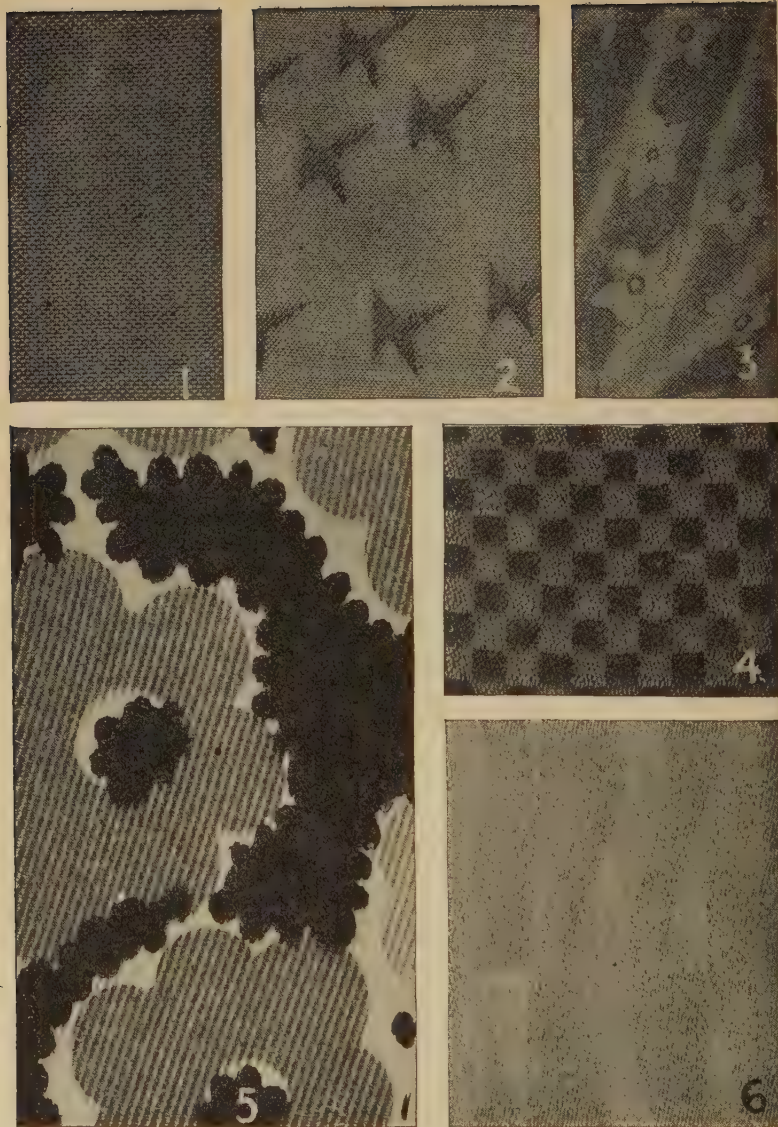


FIG. 167. Rayon and Silk Fabrics. 1. Matté Alpaca; 2. Alpaca with Jacquart Design; 3. Jackard Satin; 4. Cross-dyed Fabric; 5. Printed—Heavy Surah; 6. Jacquard Design, with Raised Bright Rayon Pattern on Dull Silk background.

To decorate a woven design Rayon is found in a great variety of textiles, such as crêpe, rep, basquet weave, flannel or marquisette. In Nos. 1, 2 and 3, of Fig. 170, we are showing three fabrics in which Rayon is used in the white.

A Rayon thread twisted around a woolen thread is usually the medium by which beautiful frosted effects are secured in georgette or twill. The Rodier asperic shown in No. 4 which is almost as popular as the far-famed Kasha is made of an extremely soft woolen thread in twill construction around which is bound a Rayon thread, curled, which suggests a new version of the popular frisca family. The Diagonella, another Rodier fabric in which Rayon staple mixed with wool before the latter was made into yarn, is used; has an appearance which is subdued enough for the most conservative. Yet, the Rayon in the mixture buried within the wool in white diagonal weaves gives just that much of light necessary to lift this coating from the category of plain cloth, to the novelty class. In No. 5 is shown a Rayon and wool ratiné. In solid colors Rayon is also used in gold or silver to achieve the metallic effect otherwise accomplished by tinsel. Rayon, however, has an advantage over the latter in the fact that it does not tarnish and is softer.

A distinct rough surface which is such an important fashion element is accomplished by the use of flakes or knobs of Rayon. In Nos. 1 and 3, Fig. 171, we are showing these two effects obtained by the use of fancy yarn. The former is a Meyer fabric and the latter one from Rodier. They are both used for sportswear or coats.

RAYON AND COTTON

As early as twenty years ago Rayon was used as a decorative medium by cotton mills. It was employed as an additional filling to create small patterns or used as a striping in

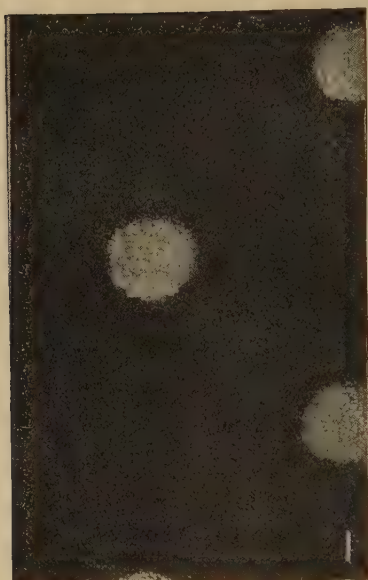


FIG. 168. Rayon and Silk Fabrics. 1. Printed Transparent Velvet; 2. Cut, Cross-dyed Velvet; 3. A Fabric in which Pattern was made by Crushing; 4. Afghan Velvet.

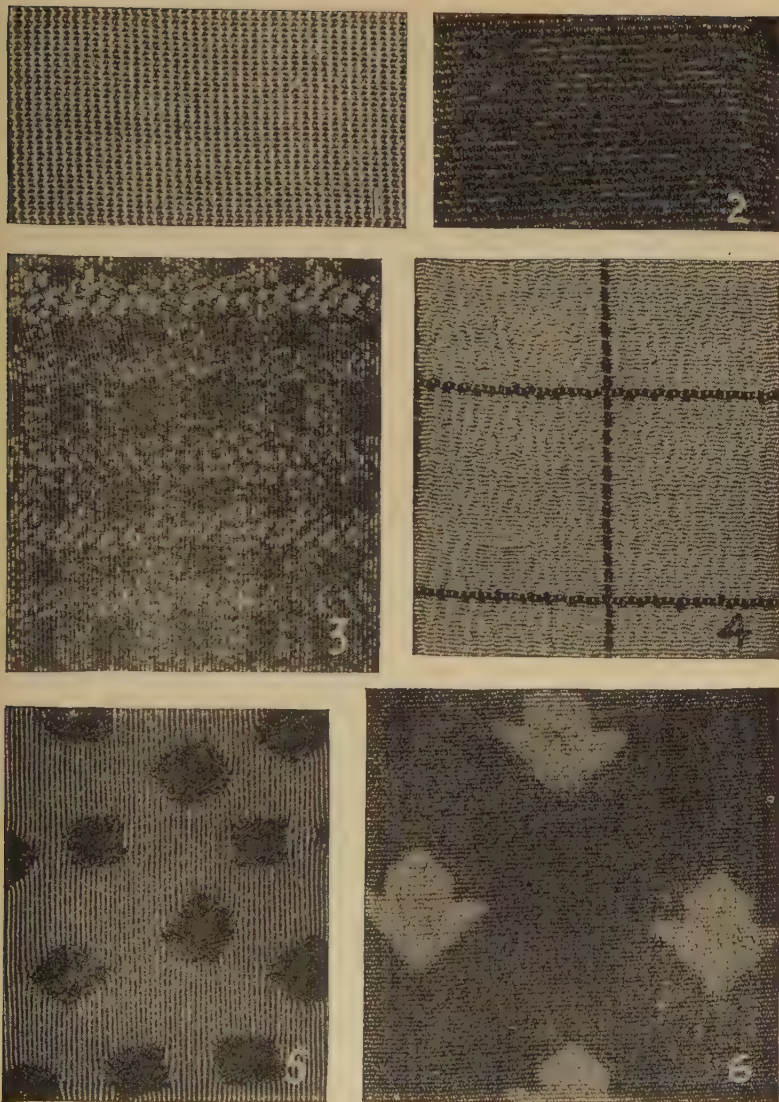


FIG. 169. Rayon Warp-wool Filled Fabrics. 1. Cross-dyed Alpaca; 2. Cross-dyed Heavy Faille; 3. Rayon and Wool Printed Crêpe Satin; 4. Flaminga Type with woven effect.

the warp. The Rayon decorated gingham at one time constituted an important part of the sales of the wash goods departments of the retail stores and the mail-order houses. For the last few years, however, their popularity declined in spite of the fact that they have been produced in very beautiful designs, such as Chinese brocades, small clipped figures and jacquard patterns. The relative percentage of the total wash goods sales of a representative group of retail stores has declined from 2 per cent in the spring and summer of 1926 to 1 per cent in the same period of 1928. This decline was probably due to the increase in vogue of printed designs as against the woven effects.

COTTON WARP-RAYON FILLED FABRICS

A plain weave fabric, somewhat similar to the so-called cotton print cloth is made with 150 denier Rayon filling and a cotton warp. This fabric is usually quite shiny, which gave it the name of alpaca. It is sold in plain colors or in printed designs and is used for women's and children's dresses and undergarments, for linings and curtains. A much finer fabric usually designated by the name of Rayon and cotton radium is gradually replacing the alpaca for all better uses. This construction is made with a finer cotton and 100 denier multifilament Rayon filling. A still greater refinement has taken place in England in the production of cotton warp-Rayon filled fabrics. Cotton yarn as fine as 100 is employed in making crêpe warp while 80 or 100 denier multifilament Rayon is used in the filling. The result is a very soft and well covered cloth of the flat crêpe type. Such fabrics are used in England and in Canada in a large way for women's and children's underwear and dresses. They possess the required fine-

ness, softness and drapiness needed for street dresses and are easy to wash. Cloths of similar construction are being launched in this country. The Rayon alpacas, radiums and flat crêpes are an important item of the sales of the wash goods departments of retail stores in this country as they amount to approximately 7 per cent of their total business.

In No. 2, Fig. 172, is shown a Rayon decorated gingham while No. 1 is a Rayon and cotton flat crêpe which is yarn dyed in striped pattern so appropriate for dresses similar to the one made of the striped silk broadcloths. In No. 3 is shown a Rayon printed alpaca with jacquard design.

Approximately 5 per cent of the sales of the wash goods departments of retail stores is taken by fabrics made with crêpe cotton yarn in combination with Rayon or with silk which are woven in somewhat open construction such as crêpe and Ratiné shown in Fig. 172, Nos. 4, 5 and 6. These fabrics have lately been gaining in popularity over those made of cotton and silk.

Another illustration of Rayon used as a decorative medium for a cotton fabric is given in Fig. 173 where a clipped Rayon flower effect is made on a cotton voile ground.

Cotton warp-Rayon filled fabrics of a heavier weight than the alpacas used for dress goods are made for linings of men's suits, often with small dobby designs such as No. 3, Fig. 173.

Rayon and cotton taffeta is another variety of a plain weave which is made of a heavier weight than any of the above described. It is used extensively for interior decoration.

Large quantities of Rayon bedspreads and damasks are made, in which Rayon is mostly employed undyed while the cotton is yarn dyed in many colors. Rayon and cotton marquisette is another important fabric for interior decoration.

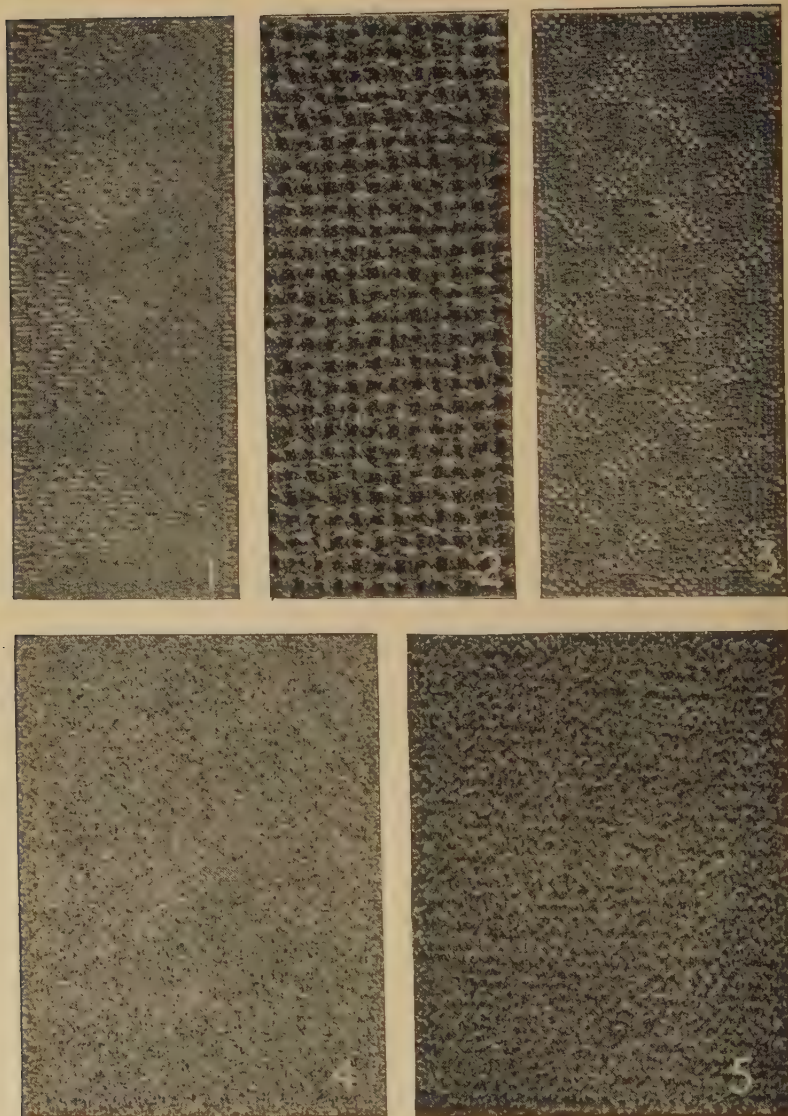


FIG. 170. Rayon and Wool Combination. 1, 2, 3. Rayon used in White; 4. Rodier Asperic made of Soft Woolen Thread; 5. Rayon and Wool Ratine.

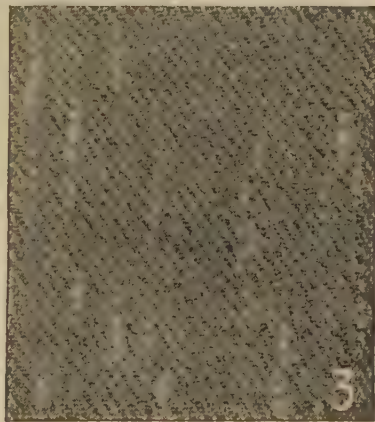
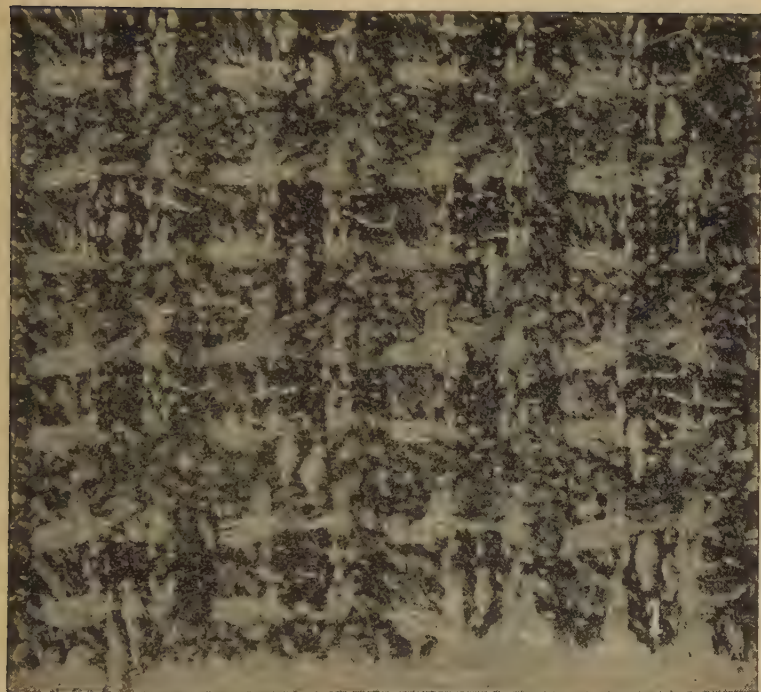


FIG. 171. Rayon and Wool. 1. Meyer Fabric with knots; 2. Rodier Diagonacea; 3. Fabric with Rayon Flakes.

Cotton warp with designs printed on them are woven with Rayon filling to create attractive cretonnes which are richer and softer than the ones made entirely of cotton.

RAYON WARP-COTTON FILLED GOODS

The most important fabrics in this group are the satins and twills used for men's linings. In illustration No. 1, Fig. 173, is given an example of a Rayon twill made for this purpose which has a herring-bone stripe made on a dobby loom. These fabrics are often made with jacquard designs. For overcoats heavier weights are used than for suit linings. The Rayon twill and alpaca described previously are considered as being more attractive than the cotton warp-worsted filled alpaca which they have been gradually replacing. Such a Rayon fabric of good construction is stronger dry or wet. They are smoother and softer, which makes them easier to put on and helps to keep them clean.

A Rayon warp-cotton filled satin of a heavier weight is used for women's slippers and upholstering of furniture.

Attractive brocaded designs are made for women's linings, negligees, cheaper dresses and interior decoration.

In illustration No. 2, Fig. 173, is given a Rayon and cotton corset which is made with jacquard design and is representing an important group of fabrics.

RAYON CONTRIBUTION TO MODERN ART IN INTERIOR DECORATION

Art is always an expression of the contemporary life. The spirit of our time has the following distinct characteristics: strength and directness of expression, complexity of contrasts

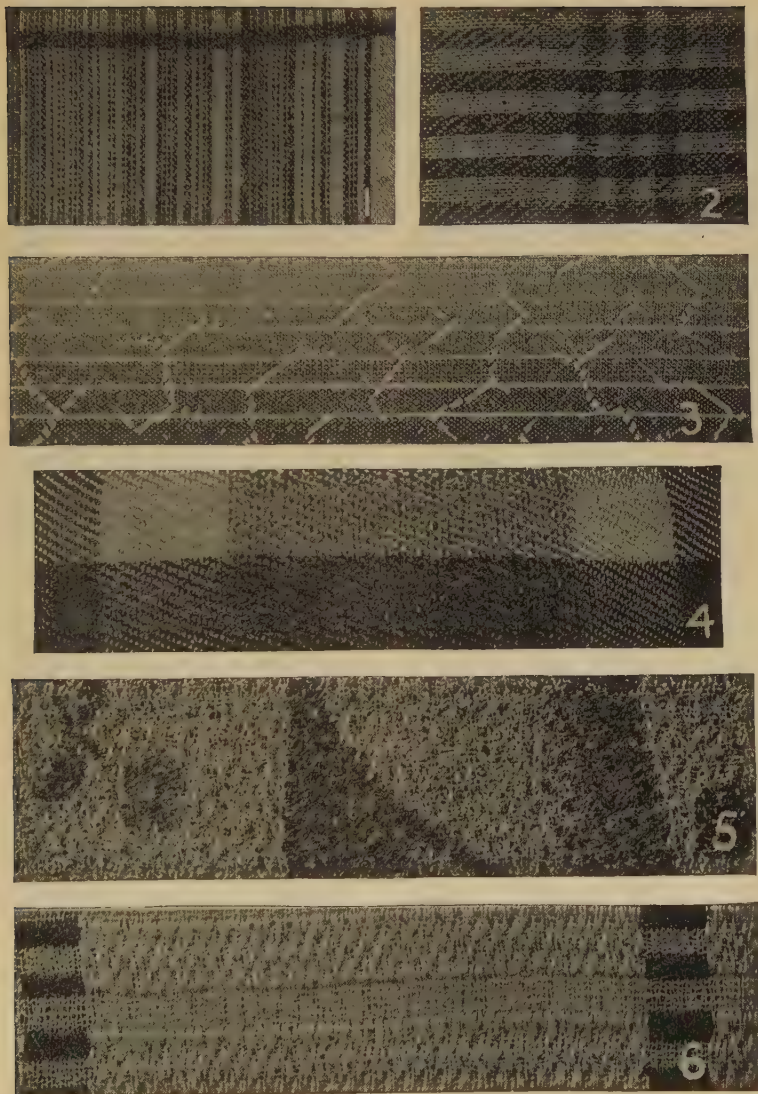


FIG. 172. Rayon and Cotton. 1. Rayon and Cotton Flat Crêpe (Yarn Dyed in Striped Pattern); 2. Rayon Decorated Gingham; 3. Rayon Printed Alpaca with Jacquard Design; 4. Crêpe and Ratine; 5. Made of Crêpe; 6. Cotton yarn combined with Rayon and Silk, Woven in Open Construction.

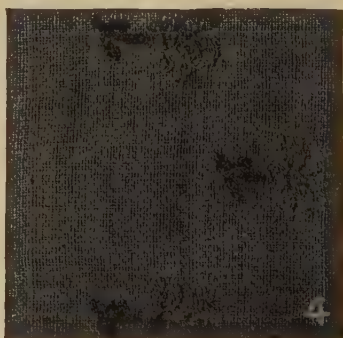
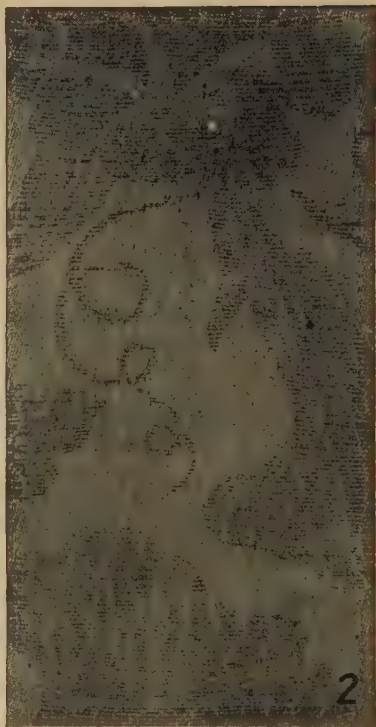


FIG. 173. Rayon and Cotton. 1. Rayon Twill with Herring-bone Stripe Made on Dobby Loom; 2. Rayon and Cotton Corset Material in Jacquard Design; 3. Cotton Warp-rayon Filled Fabric in Small Dobby Design; 4. Clipped Rayon Flower on Cotton Voile Ground.

and luxury. It is natural, therefore, that modern art should embody the earmarks of these characteristics.

We are interested in machinery, invention and industry. We have the spirit of adventure and we long to experiment. The ease of communication has placed at our disposal the resources of the whole world.

Most of the textiles have a distinct personality. Jute is thick, strong, irregular, heavy and stiff. It suggests strength and ruggedness and has a primitive feeling which suggests outdoor life. Cotton is dull and frugal. Rayon is full, soft, rich and glittering. It can be fine and at the same time heavy and strong. It was the genius of Rodier coupled with the French love for experiment that brought these three materials together in fabrics of irregularity of texture vitalized by the contrasts of the above-described elements.

The following tables show Rayon woven fabrics with the type of loom best suited for their production and the type of dyeing and finishing used for such cloth:

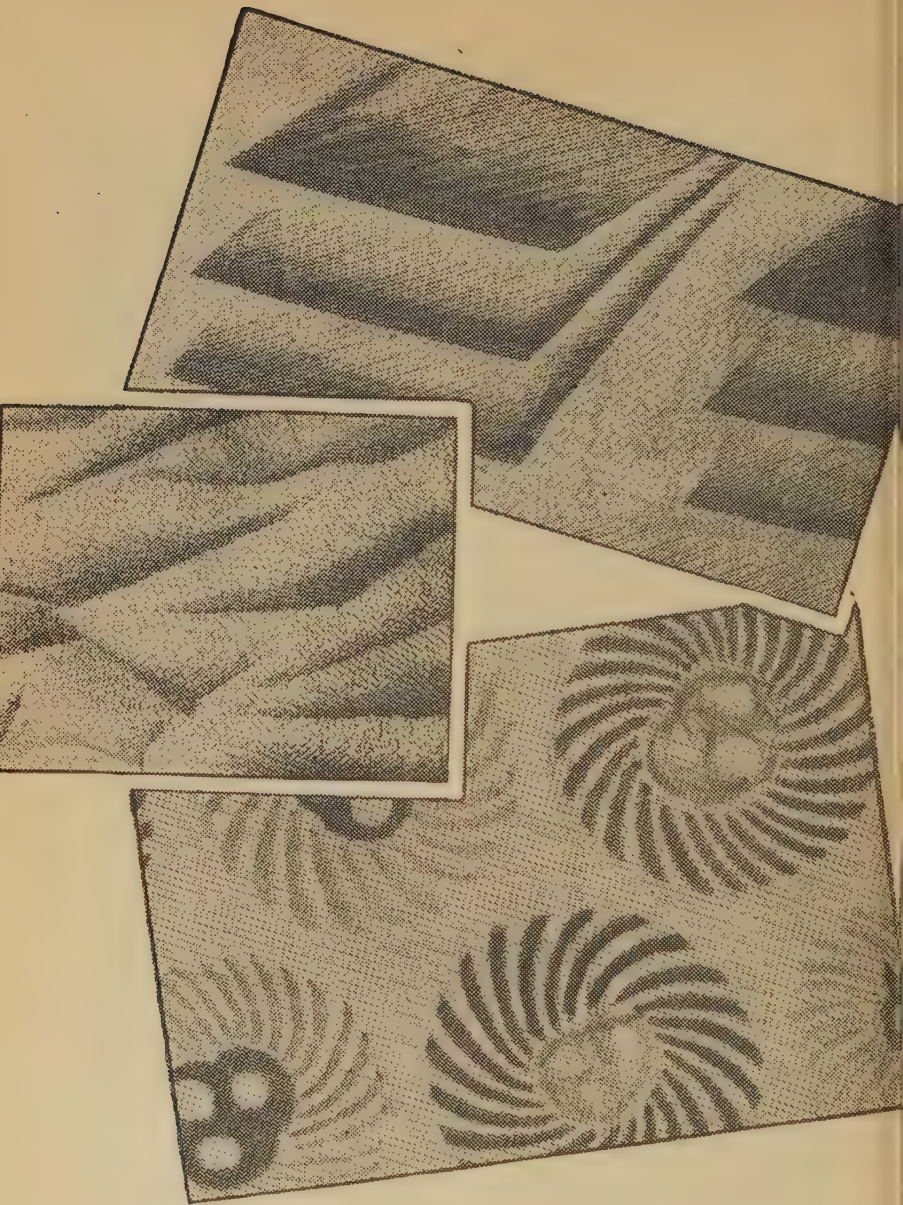


FIG. 174. Rayon containing Modern Art Fabrics for Interior Decorations.

Top—Modern art design woven with a cotton, linen and Rayon mixture in the proportions of 26 per cent cotton, 52 per cent linen and 22 per cent Rayon. Weight is 510 grams per square meter.

Left—A lighter weight furnishing Rayon and cotton fabric carried out in a range of contrasting colors.

Right—Influence of modern art is also apparent in this fabric produced from a jute, Rayon and cotton mixture in the proportion of 31 per cent jute, 30 per cent Rayon and 39 per cent cotton. Weight is 370 grams per square meter.

All three fabrics are from Rodier, Paris.

(Courtesy Daily News Record, New York.)

TABLE 91.—RAYON AND SILK

Rayon as a Part of Warp or Filling or Both	Loom				Dyeing			
	Plain	Box	Dobby	Jacquard	Skein		Piece Dyeing	
					Plain	Multi-colored	Printed	Warp Print
Rayon striped shirts, sleeves and linings	✓		✓	✓		✓		✓
Rayon decorated gingham		✓	✓	✓		✓		✓
Rayon in crêpes, ratiné, eponge, etc.	✓	✓	✓	✓		✓		✓
Rayon decorated corset cloths		✓	✓	✓		✓		✓
Rayon decorated voiles (clipped or swivel)		✓	✓	✓		✓		✓
Rayon Warp and Silk Filling								
Taffeta	✓							✓
Surah								✓
Twills and Satins: slips, linings, draperies			✓	✓		✓	✓	✓
Satins (heavy) lunasol type; dress and cloaks			✓	✓		✓	✓	✓
Crepes	✓		✓	✓			✓	✓
Crepe satin		✓	✓				✓	✓
Matté Alpaca	✓						✓	✓
Matelassé								✓
Satin teutré			✓	✓				✓
Silk Warp and Rayon Filling								
Taffeta, casket and hat linings	✓							✓
Canton Crepe	✓							✓
Rayon decorated, voile, crepes, metal cloth		✓	✓	✓		✓		✓

TABLE 93.—RAYON AND COTTON

	Loom				Skein		Dyeing		
					Plain	Multi-colored	Cross-dyed	Printed	Warp Print
	Plain	Box	Dobby	Jacquard					
Cotton Warp, Rayon Filling									
Alpaca: dress, underwear, women's linings, curtains, etc.....	✓		✓	✓		✓	✓	✓	✓
Dimitry: tissue, check plaids.....	✓	✓	✓	✓				✓	✓
Radium: (finer Rayon and cotton); dress underwear, etc.....	✓							✓	✓
Taffeta (heaviest cloth): upholstery, drapery, bedspreads.....	✓					✓			✓
Chintz (heavier quality): upholstery.....	✓					✓			✓
Alpaca (medium weight): men's linings.....	✓		✓	✓					✓
Leno (open mesh underwear fabric).....	✓		✓	✓			✓		✓
Flat crepe (fine cotton creped warp).....	✓		✓	✓		✓	✓		✓
Crepe (heavy cotton yarn, open appearance)	✓	✓	✓	✓		✓	✓		✓
Ratiné, éponge.....	✓		✓	✓		✓			✓
Twill, satins.....	✓		✓	✓	✓				
Bedspread, combination bedspread and blanket.....		✓	✓	✓	✓	✓			
Table damask.....			✓	✓	✓	✓			
Drapery and upholstery.....			✓	✓	✓	✓	✓		
Marquessette for scrim.....	✓				✓				✓
Rayon Warp, Cotton Filling									
Twill, satins: men's, women's linings.....	✓		✓	✓					✓
Satins (heavy): slippers, hats, upholstery			✓	✓					✓
Crepes (Canton).....			✓	✓					✓
Bedford cord.....	✓	✓	✓	✓					✓
Draperies.....			✓	✓		✓			
Ribbed fabrics (women's linings).....			✓	✓		✓			✓

TABLE 94.—THE USE OF RAYON CONTAINING FABRICS IN DIFFERENT KINDS OF WOMEN'S APPAREL
IN ACCORDANCE WITH THE 1928-1929 MODE

	Crepe	Satin	Velvet	Lace	Pecroquet Crepe	Twill
Negligees.....	✓	✓	✓	✓	✓	✓
House and Summer Dresses..	✓				✓	✓
Sport Dresses.....	✓		Jackets		✓	✓
Afternoon Dresses.....	✓	✓	✓	✓		
Evening Dresses.....	✓	✓	✓	✓		
Coats.....	✓	✓	✓			
			Rayon and Wool Georgette			
	Brocade	Rayon and Cotton Crepe				
Negligees.....	Stripes	✓	✓	Radium Cravat	Voile P. K.	Dimity Rep.
House and Summer Dresses..		Rayon and wool twill	✓	Moiré	Brocades	✓ Net
Sport Dresses.....	Crepe satin		✓	✓	✓	Dragon satin
Afternoon Dresses.....	✓	Matelassé				
Evening Dresses.....	Ottoman					
Coats.....						
		Georgette	Ratiné		Taffeta	Ciré
	Organdie	✓	✓	Rayon clear gingham		
House and Summer Dresses..	Alpaca		✓	Marrocain crepe	✓	Jackets
Sport Dresses.....		✓		✓	✓	✓
Afternoon Dresses.....					✓	
Evening Dresses.....						
Coats.....		Rayon and wool asperella type				

TABLE 95.—USE OF RAYON CONTAINING FABRICS IN INTERIOR DECORATION

Casement Cloth..	Voile	Marquissette	Lace	Net	
Drapery.....	Taffeta	Damask	Satin	Chintz	Plush
Wall-Coverings...		✓			
Upholstery.....		✓	✓	✓	✓
Bedspreads.....	✓	✓	✓		
Drapery.....	Velours	Fur-Fabric	Modern Art		
Wall-Coverings...			✓		
Upholstery.....	✓		✓	Rep	Moiré
Bedspreads.....	✓	✓			✓

TABLE 96.—MISCELLANEOUS RAYON CONTAINED GOODS

Floor coverings, bath-mats, rugs, fur fabrics.

Tickings: stripes and Jacquard designs.

Bed-sheets, all Rayon, Rayon and silk, Rayon and cotton.

Table-cloths, Rayon, linen, Rayon and cotton, plain-colored, multi-colored.

Lamp-shades.

Couch-covers.

DYEING

Before dyeing Rayon yarns, it is necessary to remove all sizing and oil, and in the case of Viscose yarn there must be no trace of free sulphur. Apart from these necessary precautions very little if any special preparation of the yarn, such as scouring and bleaching is necessary, because Rayon producers realize the importance of level dyeing and prepare the yarn in a fairly pure state.

When bleaching is necessary, and it is so only when dyeing light or medium shades, it is carried out by first steeping the

yarn in a warm solution of soap or soluble oil and then rinsing in clean warm water. The actual bleaching is done by one of the following methods:

- (1) In a weak solution of calcium hypochlorite followed by a neutralizing bath of hydrochloric or sulphuric acid.
- (2) Sodium hypochlorite, requiring no neutralizing after-treatment.
- (3) Sodium peroxide, requiring no after-treatment.

Dyeing machines for Rayon yarn differ from those used for other yarns in that they have to be especially adapted to handle a fibre of extreme weakness when wet. Rayon yarn is dyed almost universally in skein or hank form, the skeins or hanks being mounted on rollers of some hard smooth material running on ball bearings to reduce friction. These rollers revolve, turning the yarn in the dye tank and at the same time a side motion is imparted by means of an eccentric or other mechanical movement to the skeins or hanks suspended in the dye bath, in order to open up the filaments of the yarn and allow perfect distribution of the dye. All essential parts of dyeing machines are made of or lined with monel metal, hard rubber or some vitreous material.

Dyeing Various Rayon Yarns.—All of the varieties of Rayon yarns have natural affinity for basic colors, although some have more affinity than others. This affinity is in the order named, the first named having the most affinity and the last named the least: Celanese, Chardonnet, Viscose and Cupra-ammonium. Both Chardonnet and Viscose can be dyed with the use of a mordant. Chardonnet has somewhat greater affinity for basic colors than the Viscose, and for light shades acetic acid is used in the dyebath to retard the exhaustion and secure level dyeings. Viscose, having a lesser affinity, seldom requires the use of acetic acid, and for dark shades may even require a tannic acid mordant in order to obtain

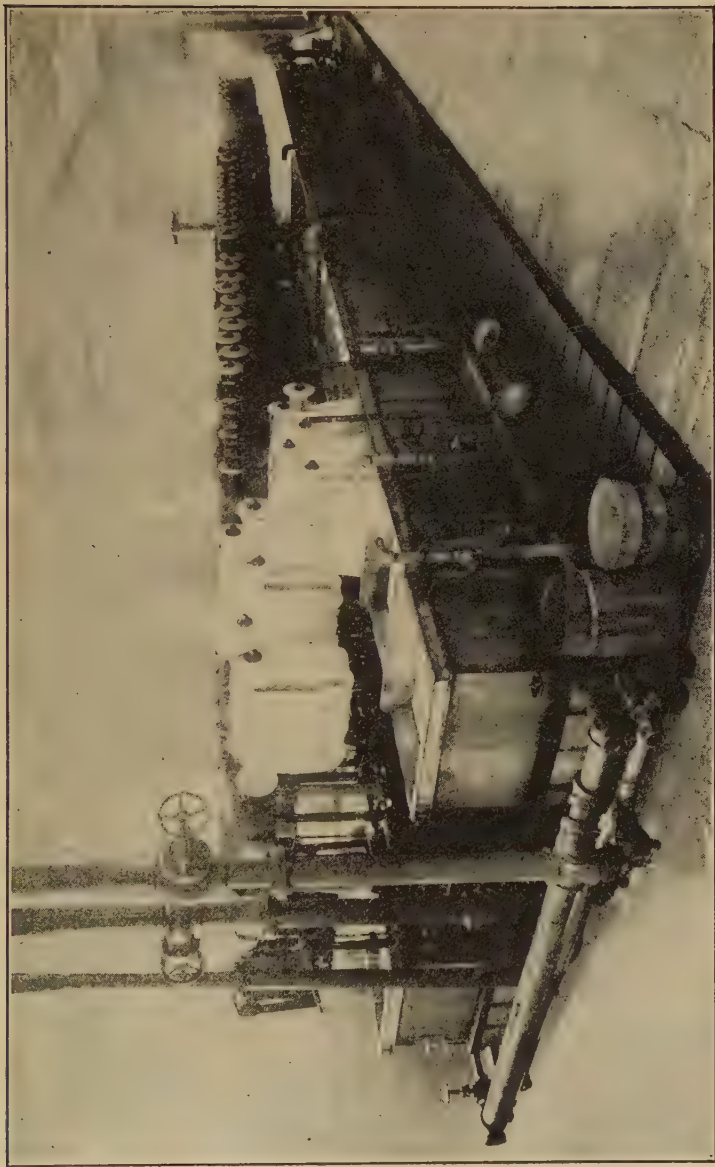


FIG. 175. Buhlman Skein Dyeing Machine. (A. W. Buhlman, 200 Fifth Ave., New York.)

a proper exhaustion of the color. The mordant used is the following: 5 per cent tannic acid, work material for several hours at 160 degrees Fahr., then drain and work cold for half an hour in 1 per cent tartar emetic, then rinse.

Cupra-ammonium Rayon has so little natural affinity for basic colors that it always requires the use of a tannic acid mordant as above given, if good results are to be obtained. Chardonnet silk has less affinity for direct colors than either the cupra-ammonium or Viscose Rayon, the cupra-ammonium having greater affinity for the direct colors than the Viscose. Thus the Viscose can be considered as being midway between the two. All three can also be dyed with sulphur or vat colors.

Contrary to these, the acetate or acetyl Rayon has practically no affinity for direct, sulphur or vat colors, but possesses a great affinity for basic colors. This interesting quality makes it of use as a white effect thread if such a material is to be made. There have been recently several processes developed for the purpose of dyeing this silk with direct, sulphur or vat colors. These processes are all very similar and are sometimes referred to as the "saponification" methods, the purpose being partly to remove from the silk the acetyl group so that it more nearly approaches its original condition of pure cellulose. This is accomplished through the use of caustic soda or sodium silicate. This method does not always produce good results, for to be perfect the amount of "saponification" should be equal throughout the surface of the filament and as can be easily understood this is rather difficult to control. It should always be remembered that complete "saponification" is not desirable on account of the loss of luster sustained and also the loss of weight and of silk-like properties.

Dyeing with Basic Colors.—As previously stated, all varieties take basic colors directly, but in varying degrees. The chief value of these products is their brilliancy of shade. The dyeing process is approximately as follows: The material is

entered to the cold dyebath and the temperature gradually raised to 140 degrees Fahr., the dyeing being then continued for 45 minutes. No mordant is necessary although the use of a small amount of acetic acid retards the exhaustion of the color and will aid in securing level dyeing. The basic colors which are recommended are as follows:

Yellow: Newport Thioflavine TG, TG Extra; Newport Auromine O.

Orange: Newport Chrysoidine Y; Newport Chrysoidine R.

Red: Newport Safranine; Newport Safranine Y.

Pink: Newport Rhodamine B Extra Conc.

Blue: Newport Methylene Blue Extra Conc.

Green: Newport Brilliant Green Crystals; Newport Malachite Green Crystals.

Violet: Newport Methyl Violete R Conc. Powder.

Brown: Newport Bismarck Brown R Extra.

Black: Newport Basic Black SB; Newport Basic Black FCG.

Dyeing with Direct Colors.—This is the class of colors used to the largest extent in the dyeing of Rayon (for the reason that they are the most easily dyed) using a process approximately as follows: The dyebath, to which the dissolved color is added, is made up to a volume of 20 times the weight of the material. The material is then entered to the lukewarm bath, which is gradually raised to a temperature of 160 degrees Fahr., and the dyeing continued for 45 minutes. The use of 10 per cent to 30 per cent of calcined Glauber's salt, depending upon the quantity of dyestuff, is required to secure a better exhaustion of the dyebath and consequently greater tinctorial value from the color used.

In the dyeing of Rayon there appears the same differences in the working qualities of various colors as appear in the dyeing of cotton, except that the colors do not work just

exactly the same on Rayon as on cotton. In the case of some of the direct colors, there is much greater affinity between the fibre and the color. These consequently exhaust more rapidly. Others exhaust more slowly and less completely. These differences make it advisable to group carefully the various dyestuffs and use in combination with each other those colors that most nearly exhaust to the same degree. The direct colors are all applicable to a greater or less extent, but the list given below names those products which are most suitable. In each case, the product named first is recommended as being the best, the others in the rotation as given:

Yellow: Newport Direct Fast Yellow B; Newport Direct Fast Yellow NN; Newport Chrysophenine XXX Conc.

Orange: Newport Direct Fast Orange RS; Newport Toluene Orange GR Conc.; Newport Direct Orange R.

Red: Newport Direct Fast Red F; Newport Benzo Purpurine 4 B Conc.; Newport Benzo Purpurine 10 B Conc.; Newport Direct Fast Scarlet G; Newport Direct Fast Scarlet 4 BA; Newport Direct Fast Scarlet 8 BA.

Pink: Newport Direct Fast Pink, EBN, EB Ex.; Newport Direct Fast Pink E 2 GN; Newport Direct Pink 2 B.

Blue: Newport Direct Blue 3 Bx.; Newport Direct Brilliant Blue G; Newport Direct Sky Blue FF; Newport Direct Sky Blue; Newport Direct Steel Blue G Conc.; Newport Direct Fast Blue SFF; Newport Diazo Black RS; Newport Developed Black BH Ex. Conc.; Newport Direct Blue 2 Bx.; Newport Benzo Azurine G Extra; Newport Direct Fast Blue RW.

Green: Newport Direct Green 2 GB; Newport Direct Green B; Newport Direct Green CY.

Brown: Newport Fast Brown BT; Newport Direct Brown RG; Newport Brown RXN; Newport Direct Fast Brown M; Newport Direct Brown CR.

Violet: Newport Direct Brilliant Violet R Conc.; Newport Direct Violet N.

Gray: Newport Neutral Gray GG Special; Newport Direct Fast Black LR; Newport Developed Black 2 BN; Newport Fast Black V.

Black: Newport Artificial Silk Black SBR; Newport Direct Black HP; Newport Direct Black EG Extra; Newport Direct Black RB Extra.

It is always advisable to use as nearly straight colors as possible as greater difficulties are encountered in dyeing mixed shades than in straight colors.

Direct Colors with Least Affinity.—There are some few direct colors that have comparatively little affinity and consequently are very useful for filling up the shade on the cotton in mixtures of cotton and Rayon. These are the following:

Newport Direct Yellow G; Newport Direct Orange 2 R; Newport Direct Orange 2 R G; Newport Direct Fast Scarlet 8 B A.

Mixtures of Cotton and Rayon.—Dyeing is started without any addition of common salt to the dyebath; that is to say, just dyestuff is used and a small quantity of soap or soluble oil or both. If during the process of dyeing the shade on the Rayon is not sufficiently heavy, common salt can be gradually added, but in very small quantity. Rapid addition or the addition of too great a quantity would cause the color to jump on the Rayon too rapidly.

Dyeing with Anthrene Colors.—The Anthrene colors are the fastest colors obtainable. They possess excellent fastness to light and severe washing; are fast to acids and alkalies, and will withstand cross-dyeing in acid liquors. They are dyed from hydrosulphite vats by dissolving the color with hydrosulphite and caustic soda at various temperatures depending on the color.

DYEING OF RAYON YARNS

Generally speaking, Rayon yarns for dyeing may be divided into two distinct classes: (1) The regenerated cellulose

type in which category are the yarns produced by the Viscose, Cupra-ammonium, and Chardonnet processes, and (2) Cellulose acetate, which differs entirely from the regenerated cellulose types in dyeing properties.

Dyeing of Regenerated Cellulose Rayon: The three processes forming the former class differ slightly in their dyeing properties but these differences are due probably to structural formation and relative affinity rather than to any other important reason. However, the mordants used with each of the three processes differ slightly for best results as explained in a preceding section of this chapter.

The conditions entering into the dyeing of Viscose yarns are similar to those in the dyeing of cotton to the extent that the same classification of dyes may be used and the behavior of the two textiles under the action of these dyes is similar.

The results obtained, however, vary because of the difference in structure between the Rayon and cotton and because of the loss in strength in the former when wet, which necessarily calls for special and greater care in handling. The greater length of dyeing time necessary with certain dyes causes great differences in the speed of winding the dyed yarns and certain mordanted dyes requiring treatment with metallic salts renders the Rayon yarns less permeable because of gumminess.

Because of its weakness when wet Viscose Rayon must be kept entirely free from stretching and rubbing when being dyed. As a result of stretching and rubbing when wet, differences in color in the fabric will appear and the filaments and threads will break. In addition to stretching and rubbing which may occur in handling, it is absolutely essential to see that all surfaces with which the materials may come in contact are perfectly smooth or fretted Viscose will be the result. The linings of dye tanks should be of a metal which

is unaffected by different dyes and which will take a highly polished surface.

The quality of water used in dyeing Viscose is of the greatest importance. It should be as soft as possible and should contain a good lubricant such as soap which will eliminate to a great extent rubbing or friction.

Rayon materials should never be wrung out like cotton for this operation will stretch them and they will never come back to shape. They should be wrapped in cloths after dyeing or washing to remove the moisture. Drying should be done at as low a temperature as circumstances will permit, usually 120 degrees Fahr. If artificial means are employed for dyeing, great care should be used to see that rapid currents of air are not permitted to play on the Viscose because this will tend to open up the threads.

CLASSIFICATION OF VISCOSE DYESTUFFS

In the coloring of Viscose the following classes of dyes are used:

- (1) Direct Cotton.
- (2) Basic.
- (3) Sulphur.
- (4) Azoic.
- (5) Vat.

Direct Cotton Dyes.—Under this heading come the ordinary dyes used for dyeing cotton and which require no mordant. It was believed that all of these dyes could be used in dyeing Viscose to the same extent and degree as in cotton but in actual practice very few of them give even results when used on Viscose. The dyeing affinities and structural formation of Rayon fibers is quite different from cotton and many

of the direct dyes are too sensitive to produce even shades with these variations in dyeing affinity and structural formations. Direct cotton dyes are still the most largely used for Viscose because of the short time necessary for dyeing but the colors obtained from such dyes are not as lasting as can be obtained from other classes of dyes.

Basic Dyes.—These dyes are extremely fugitive and while they can be applied to Viscose without the use of a mordant, this is not to be recommended. Tannic acid is a mordant used with basic dyes for Viscose and requires an after fixation with metallic salts.

Katanol is a mordant which has only recently been introduced but it has definite advantages over tannic acid or tannin in that the process of dyeing is shorter and the use of metallic salts for fixing is eliminated. Katanol is a yellow powder, soluble in dilute sodium carbonate and is applied by dissolving it first in soda ash then using from 2 to 6 per cent, according to depth of color required, in a Glauber salt bath at 190 degrees Fahr. Katanol has an additional advantage over tannin in that it produces more even shades.

Sulphur Dyes.—This class of dyes is the most uneven of all and should never be applied to Viscose except in the case of blacks or when extreme fastness is required. There are practically no sulphur dyes which can be classified as even dyeing.

Azoic Dyes.—This class of dyes, when used with Viscose, has one very definite limitation in that the dyeing of heavy shades will blind the Viscose. The dyeing produced by these dyes is very even and fast however, and considerable attention is being given to them.

Vat Dyes.—These dyes, particularly the fastest, present the greatest difficulties in their application to Viscose because of the great rapidity in manipulation which is necessary in order to get even shades. This rapid manipulation in turn

tends to stretch and rub the material which is very undesirable with Rayon. Very great skill is necessary in manipulation with these dyes to get even passable results and even then the average shades obtained are not to be compared with the results on Viscose with the other dyes except possible with sulphur dyes.

There are some soluble vat dyes such as indigosol and soledon jade green which give good results and great hopes are held out that a complete line of similar ones will be developed. In the use of vat dyes for Viscose never mix those which require a strongly alkaline vat with those which require a weakly alkaline vat for such mixtures never give satisfactory results.

CLASSIFIED LIST OF VAT DYESTUFFS

EVEN DYEING

Algole Blue 3 R	Ciba Pink B.
Algole Brilliant Red a B.	Ciba Heliotrope B.
Algole Pink R.	Ciba Red G.
Caledon Red B.N.	Ciba Violet B and R.
Caledon Violet R.N.	Cibanone Brown V.
Caledon Brilliant Purple 2 R.	Cibanone Yellow R.
Ciba Blue a B.	Durathrene Red B.N.
Ciba Grey G.	Durathrene Bordeaux R.
Durathrene Brilliant Violet R.	Hydron Orange R.
Durathrene Claret B.	Paradone Yellow A.G. New.
Durathrene Golden Orange Y.	Paradone Brilliant Violet R.
Durathrene Red R.	Indanthrene Orange R.R.K.
Durathrene Violet R.R.	Indanthrene Brilliant Violet 2
Durindone Blue 4 B and 6 B.	B.K.
Hydron Sky Blue F.K.	Indanthrene Yellow G.K.
Hydron Bordeaux B.	Indanthrene Brown 3 R.
Hydron Pink F.B. F.F.	Indanthrene Orange 3 R.
Hydron Scarlet B.B.	Indanthrene Pink B.

MODERATELY EVEN

Alizanthrene Yellow G.	Duranthrene Olive R.
Anthraflavone G.C.	Duranthrene Golden Orange 2
Algole Yellow 3 G.L.	R.T.
Caledone Red F.F.	Duranthrene Yellow G.
Caledon Yellow G.	Hydron Bordeaux R.
Caledon Jade Green.	Hydron Yellow N.F.
Duranthrene Red 5 G.Y.	Indanthrene Corinth R.K.
Duranthrene Red Violet 2 R.N.	

UNEVEN

Algole Blue C.F.	Hydron Brown G. and R.
Caledon Blues.	Hydron Navy Blue C.
Caledon Dark Blue B.	Hydron Yellow G.G.
Caledon Green B.	Paradone Black.
Caledon Black 2 B.	Indanthrene Blue R.K.
Caledon Brown B.	Indanthrene Brown R. and G.
Cibanone Orange R.	Indanthrene Grey G.K.
Duranthrene Blues.	Indanthrene Grey 3 B.
Grelanone Red 2 B.	Indanthrene Golden Orange 3
Hydron Blue G. and R.	G.

Dyeing of Acetate Rayon.—Acetate Rayon behaves in an entirely different manner towards dyestuffs compared with other fibers, including the other Rayon yarns. The latter, being hydrated or regenerated celluloses, naturally dye similarly to cotton, except that they possess enhanced affinities for dyestuffs. That acetate Rayon would behave differently than other fibres was to be expected from its chemical composition. The Rayon formerly made abroad, being fully acetylated, which made it impermeable to water, could not be dyed except by some basic colors and then only after a preliminary swelling treatment. It, however, was capable of absorbing amines or bases such as aniline, etc., which bases within the fibre can be diazotized and then coupled with other

developers to produce various insoluble dyestuffs. Thus the advent of the modern acetate Rayon, although this was known to be more permeable to water, and capable of being dyed more easily with some dyestuffs of different chemical classes, was marked by difficulties in dyeing on a commercial basis. The difficulties were in finding sufficient dyestuffs to give the necessary compound shades of the required fastness. It is to the credit of the chemists and technologists of the United States that to some extent these difficulties connected with the dyeing of this silk have been solved. The following are the dyeing methods for acetate Rayon:

- (1) Saponification method.
- (2) With those dyestuffs having a direct affinity.
- (3) By absorption of amines, and further treatment (azoic method).
- (4) By the use of the ionamines.

(1) The object of saponification is partly to remove the acetyl groups so as to regenerate cellulose (and by so doing to restore the usual dyeing affinity for these colors and also for sulphide and vat colors) on the surface of the filaments. It involves the use of caustic soda at a temperature of 75 degrees Centigrade. However, this process, owing to the difficulties experienced in getting level results in bulk practice, with also an important loss in weight, is practically obsolete. In some cases, it is still used by some garment dyers.

(2) The chief dyestuffs having a direct affinity to this silk are basic, and these are still used, especially where exceptional brightness may be wanted. They are employed with salt in the dyebath, on the whole do not exhaust well, and with exceptions have the same failings as when dyed on mordanted cotton.

(3) In this method advantage has been taken of the affinity of acetate Rayon for a large number of amines, amidoanazo bases, etc. They are taken up from the solutions

of their soluble salts, or, better, as free bases, the latter being in a fine state of division in a dispersing medium. By subsequent processes of diazotization and development, a large number of shades could be formed. This method failed on a large scale owing to difficulty in matching and insufficient range.

(4) At this time it was being recognized that those substances having an affinity for acetate Rayon were chiefly either insoluble or only slightly soluble in water. The necessity arose, therefore, to find some means of solubilizing these compounds so that they could be, by some means, applied from an aqueous dyebath. The "ionamines" are examples of these successful efforts. The ionamines are basic compounds rendered soluble by the addition of an omega sulphonic acid group. These soluble compounds are stable in a neutral bath but hydrolyzed, giving the free base in a slightly acid or alkaline bath. If acetate Rayon is present, it is immediately absorbed by it as produced and the Rayon becomes dyed. The dyeing of acetate Rayon is probably a solution phenomenon, the dyestuff being in solid solution within the fibre. Also, probably one disadvantage of all these colors is that when once on the fibre, there is difficulty in stripping.

Finishing.—Under this heading will be considered the processing of fabrics whether of Rayon alone or Rayon mixtures. The processes may be divided as follows:

- (1) Cross-dyeing.
- (2) Printing.
- (3) Finishing.
- (4) Laundering.
- (5) Dry Cleaning.

(1) *Cross-dyeing.*—Having described the dyeing processes of the various Rayon yarns alone, it will be of interest to consider the dyeing of fabrics consisting of mixtures of

different Rayon yarns and mixtures of Rayon yarns with other fibers. The ordinary so-called cotton dyes have no affinity for acetate Rayon and do not stain it and similarly the dyes used for acetate Rayon have no affinity for cotton, therefore, the possibilities of dyeing effects under these conditions can readily be conceived. The same possibilities exist in mixtures of Rayon yarns so that many beautiful effects are being obtained with combinations of acetate and Viscose.

With mixtures of cotton and acetate, it is desirable that the cotton be as clean as possible, as no keir boiling can be given owing to the action of an alkali on the acetate yarn. Such condition, however, does not necessarily apply to combinations of cotton and Viscose because the latter is not affected by alkalies.

In mixtures with acetate Rayon, whether with other Rayon yarns, or other fibers, it must be remembered that the dyeing of the acetate takes longer because of its slower rate of absorption. To offset this condition more color is used in the dyes but great care must be exercised to prevent uneven dyeing. When combinations of various Rayons or Rayon and other fibres are to be dyed and the mixture includes acetate, the acetate is usually dyed first. The demand for fabrics of Rayon with other fibers is very large because of the beautiful effects which can be produced by cross-dyeing.

(2) *Printing*.—The problems encountered in the printing of fabrics containing Rayon alone or in combination with other textiles are similar to those discussed under cross-dyeing. Fabrics containing Rayon yarns of the regenerated cellulose group—Viscose, cupra-ammonium and nitro-cellulose—may be printed and treated for the main part exactly like cotton, the principal precautions being those necessitated by the weakness of such yarns when wet. Such fabrics should never be dried by passing through wringing machines, but in the standard centrifuge or whizzer. Fabrics containing ace-

tate Rayon need different dyes as described under cross-dyeing. In fact, the conditions in both processes are practically alike.

When fabrics are to be printed, it is necessary for the printer to know what kind of Rayon it contains and it is most desirable that the particular brand of the yarn be known in order to facilitate the printing process and get the best results. It is essential that all sizing and oil be removed before printing, therefore, the goods should be properly bleached.

In printing all-Rayon fabric, one of the chief cares of the technician must ever be the preservation of the luster of the Rayon threads. Only the most transparent and easily removable thickenings should be employed for the preparation of the printing colors and excessively high temperatures should be avoided.

The patterns and designs printed on Rayon fabrics are almost as varied as on calico and it is possible to produce prints in the most permanent colors on such fabrics. It is to be highly deprecated that in view of the fact that Rayon fabrics can be printed with permanent colors, many such goods have been placed on the market printed with colors which have faded and run at the first wash. Such short-sighted policies never succeed and in an industry so young as the Rayon they are liable to retard its growth considerably.

(3) *Finishing*.—The finishing operation on Rayon fabrics is to make them in appearance as near silk as possible. This operation is performed on finishing machines, those used for cotton or silk finishing being both applicable. The cotton finishing machine being arranged throughout to increase the luster of cotton is not on that account as desirable for Rayon as is the silk finishing machine.

The finishing machine performs all of the necessary operations in the finishing process such as: (1) conditioning, (2)

calendering, (3) stretching, (4) drying. In the conditioning operation the fabric or cloth which may or may not be in a roll is dampened evenly by sprays of water or other suitable means. The material is then passed through the calendering rolls where luster is added. It then is stretched or opened out to the desired width and finally the material is dried.

(4) *Laundering*.—In laundering Rayon fabrics or cloth many problems were encountered by the launderer for one of the greatest limitations of Rayon was and still is, in a lesser degree, the question of its lack of strength when wet. Difficult problems arose in the laundry with goods made from Rayon yarns by the different processes and the idiosyncrasies of each had to be studied and learned. A condition dangerous to all yarns is that of using water of too high a temperature—above 140 degrees Fahr. If the water is too hot with acetate yarns, they melt and with the other three they become scorched. The question of the kind of soap and quality of water are important factors and here again the process used in producing the yarn has to be considered. Then again, the ironing operation brings in the factor of heat and were the same temperatures used on hand irons or steam calenders to be used on Rayon goods they would be spoiled by scorching, melting, lack of luster, etc. The ordinary steam pressure of 60 pounds per square inch used on steam calenders in laundries on cotton and other goods should be reduced to about 5 pounds per square inch for Rayon goods.

Because the volume of Rayon goods handled by laundries is comparatively small—about one-fiftieth of the volume of cotton goods—the method of ironing is still one of hand and is necessarily an expansive one, but as the volume increases and conditions warrant doing so the calender method or some other of greater economy will be employed. The fact that different laundering conditions exist with acetate and other Rayon yarns, and the difficulty of distinguishing between the

different yarns in the various goods, the problems of the launderer are difficult that the method used must be one of compromise, satisfactory to all kinds of yarns and they must all be treated alike until other methods are developed.

While Rayon goods lose strength when wet, they regain their original strength when dried. Rayon does not shrink in volume by becoming wet but if not handled properly the goods will stretch and become distorted.

(5) *Dry Cleaning*.—So general has become the use of Rayon in outer garments and dress materials as well as in furnishings that the problems of dry cleaning came up for solution, for unquestionably this method of cleaning is most desirable and satisfactory in preserving the finish, shape and appearance of all delicate materials. As in the case of laundering, so in that of dry cleaning, the conditions between goods containing acetate yarns and cellulose yarns, differ greatly, but here again the solutions have resulted in improved technique and more efficient methods in the industry.

The process of dry cleaning is especially adaptable for preserving the luster, color and finish of Rayon goods when the proper solvents are used, but the public is warned against using indiscriminately the many patented stain removers on Rayon goods for if this is done accidents will occur and neither the Rayon nor the cleaner are to blame.

DELUSTERING

One of the main objections raised against Rayon is its brilliant sheen or metallic luster, and considerable time, effort and money have been expended by Rayon producers, research laboratories, and chemists in the attempt to tone down this high luster to the appearance of silk without detracting in any way from the desirable qualities of the

Rayon. A method of doing this is described in British patent No. 285,958 wherein a solution of salts or acids (hydrochloric, sulphuric or acetic acid and sodium sulphate) is intimately mixed with the Viscose as it passes to the spinning nozzles, after which it is spun in the usual coagulating baths. Another method sponsored by the N. U. Nederlandsche Kunstseidenfabriken is by mixing in, during the preparation of the cellulose solution, sulphates, sulphur compounds, thiosulphates, polysulphates and similar chemicals. All these chemicals decompose during the subsequent manufacturing operations, leaving the sulphur adhering closely to the yarn. This sulphur cannot be removed by washing with soap in either hot or cold water, but care must be exercised not to use chemicals which would remove it. When dyeing yarns so treated, it is important that dyes free from sulphur be used, otherwise the sulphur will be removed from the yarn which will regain its luster.

Delustered yarn is produced by Rayon manufacturers under trade names; that produced by the Viscose Company of America being known as "Dulesco," and that by the DuPont Rayon Company as "Lolustra."

CHAPTER XVIII

MEASURING AND TESTING RAYON YARNS

IN order to cover completely all the data which enters the field of tests for measurements, definitions, control tests, etc., it would require a voluminous book, but since it is the author's purpose to make this volume only a general outline on the subject of Rayon, it is limited in all chapters as it is in this one.

MEASURING

Measuring the Size of Yarns.—Yarns are fine or coarse, according as they are thin or thick, which, of course, affects their weight per given unit of length. The size or count of a yarn is expressed by some number which means the weight of a given length as expressed in chosen units or weight. Different standards are employed in different countries for the various fibers of commerce. The English system is most extensively employed for numbering woolen, worsted, cotton and linen yarns, whereas the French system is mostly used for numbering silk and Rayon yarns. (See tables in Appendix for details.)

Since there is no uniform system for yarn numbering, as the whole matter is in a state of some confusion, a simplification of the present systems of yarn counting would be a great advantage, but the testing apparatus has been standardized to present practices and any change would require a great readjustment throughout the textile industry.

Standard Size of Cotton Yarns.—The number or count of a cotton yarn in the English system is the number of hanks of 840 yards each requisite to weigh one pound. The English system is in common use in England, America, India and Switzerland. In the French system the cotton yarn is the number of hanks of 1000 meters each requisite to weigh 500 grams. Yarns made up by doubling or twisting multiples of standard counts are denoted as 2-20's, 3-20's, etc., indicating the number of standard count threads in the ply.

Standard Size of Woollen Yarns.—In the English system the size of woollen yarn is expressed as the number of "runs" of 1600 yards each in one pound, or the number of 100-yard lengths in one ounce. In the American system, the size of a woollen yarn is indicated by the number of "cuts" of 300 yards in one pound. The grain system is quite generally used. In this system the size or count of the yarn is indicated by the weight in grains of a 20-yard length.

Sizes of Worsted Yarns.—In the English system the worsted yarn number is the number of hanks of 560 yards in one pound. In the French metric system the worsted yarn number is the number of 496-yard lengths in one pound. The latter system of sizing is understood when French worsted yarns are offered for sale. The grain system is also in common use for numbering worsted yarn. In this system the yarn size or count is the number of grains in a 20-yard length.

Sizes of Linen Yarns.—The basis for numbering linen yarns is the number of "cuts" of 300 yards in one pound.

System of Numbering Silk Yarns.—The size of raw silk yarn is expressed in "deniers" per 450 meter lengths. The denier is a unit of weight corresponding to 5 centigrams. It came into use in Caesar's time and was the weight of the "denarius" a small Roman coin. The actual value of the "denier" has changed with time but has been fixed by international agreement (Paris conference, 1900) at .05 gram.

A silk yarn of 150 deniers is one of such a size that a length of 450 meters would weigh 150 times 5 centigrams.

System of Numbering Rayon Yarns.—The same system of numbering is applied to Rayon yarns as is applied to the other textile fibres. Rayon is a combination of several single filaments which are twisted together to form one thread. The thickness of one filament is obtained by the number of grams in a certain length and calling the result “deniers” or titer, which is in a single filament from 5 to 10 deniers. The newest achievements furnish Rayon whose single filaments are as low as 1 denier, which means that they are even finer than the natural silk threads.

The American Committee recently adopted the system of numbering Rayon yarns by the number of grams in a 1000-meter length giving as a result the “denier.” This value is, of course, very close to the international legal denier. An international metric system of yarn has been proposed to apply to all yarns. In this system the yarn count is the number of meters of yarn in one gram.

To determine the titer of the Rayon, it is necessary to have it stored under normal moisture conditions, that is, about 65 per cent of the saturation value. The metric titer or deniers is the weight of a hank of Rayon, 900 meters long in grams. The proper length of the yarn is reeled off a larger hank which has been stored in the moisture chamber for several days. The thread is fastened to the hook of the denier-scales and the deniers can be read off from the scale, Fig. 176.

If necessary to determine the titer on a short thread, its length must be measured, its weight taken, and the deniers determined by figuring back according to the length. The luster of the silk thread varies with the cross-section of the thread. An expert on Rayon, therefore, will be able to state the manufacturing process from the luster. The cross-section

of nitro-Rayon is irregular, that of cupra-Rayon round or square, and that of Viscose-Rayon flattened. Nitro-Rayon, therefore, shows a brilliant luster while copper or Viscose

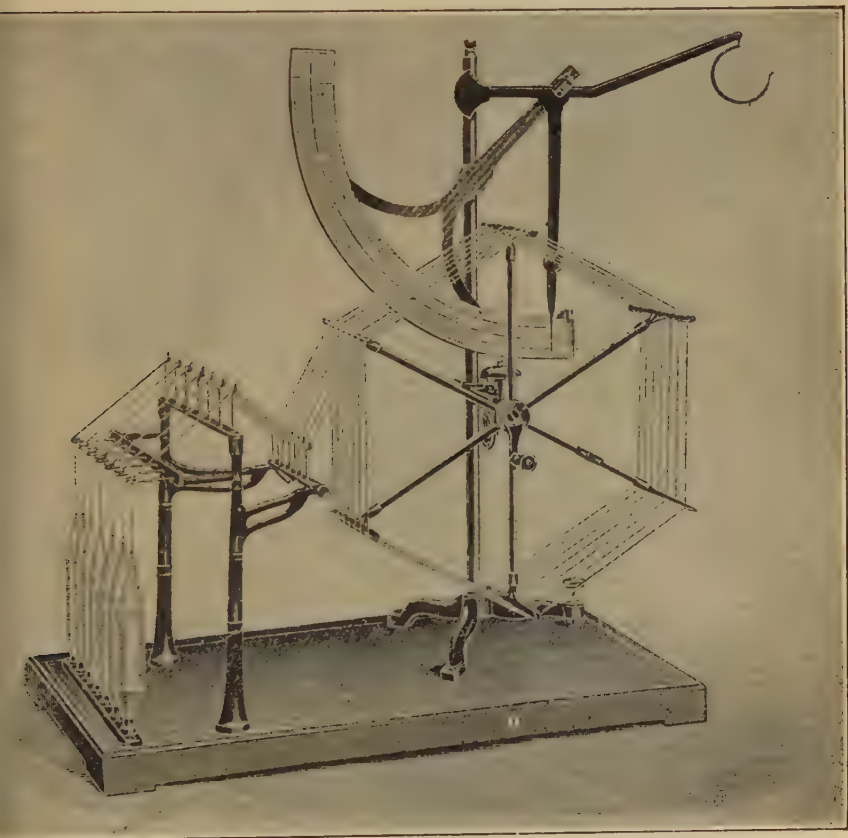


FIG. 176. Titering or Numbering apparatus.

Rayon have a more or less uniform and quiet surface shimmer. Viscose-Rayon can further be distinguished by its surface, which is rough on account of gas bubbles which are formed and escape during the coagulation period.

Rayon normally contains about 11 per cent water. If a larger percentage is present it points to an intentioned load-

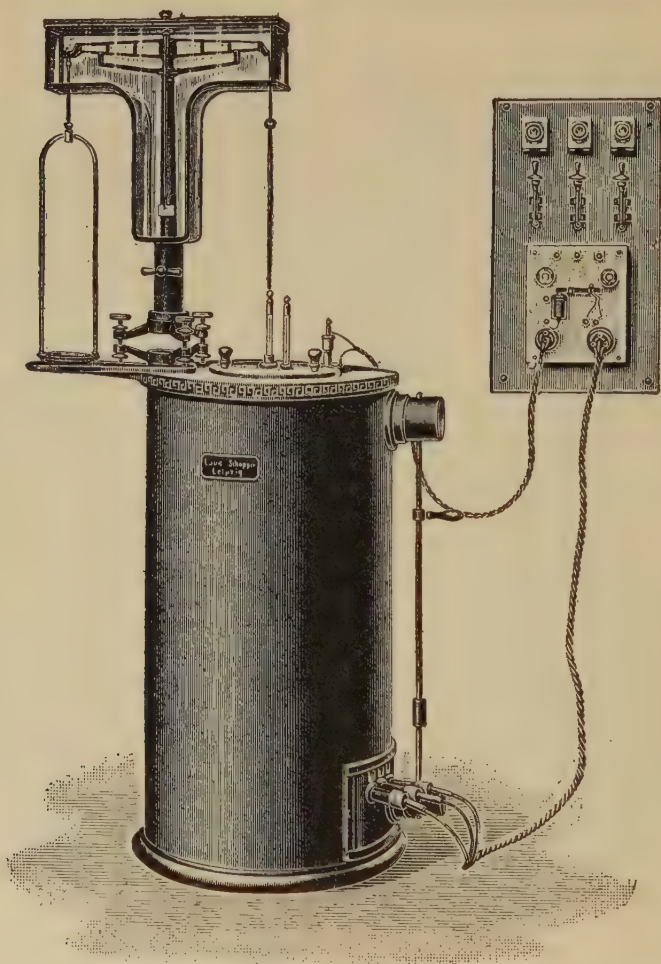


FIG. 177. Electrically Heated Conditioning Oven (Schopper Leipzig).

ing. This increases the weight and can be considered as an adulteration. The estimation of water present can be carried

out by placing several hanks of silk in the drying or conditioning oven, where the drying has to be continued until constancy of weight has been reached. The weighing of the hanks has to be done in a closed vessel because the dry Rayon absorbs water rapidly if in contact with the air, and it would be impossible to obtain constancy of weight. The conditioning oven (Fig. 178) is equipped with a balance and the dried Rayon can be weighed within the vessel. In this way an accurate estimation of the water content can be made.

TESTING

Tensile Strength and Elasticity or Elongation.—Tensile strength of a thread is the maximum strength with which the thread will resist breaking by straight pull. This strength is expressed in weights divided by the number of deniers, and the result multiplied 100 times gives us the tensile strength in percentage. For instance, if Rayon of 120 deniers tears at a load of 180 grams, then the tensile strength amounts to 150 per cent. The tensile strength varies greatly with the moisture of the Rayon. This determination ought to be made on dry and wet Rayon in order to have reliable results. But it is impossible to work with dry Rayon in practice because during the test the moisture conditions change rapidly, and to prevent this, extensive precautions would have to be made. Another reason why the tests are made on the moist Rayon is that this is the condition of Rayon in commerce and use and it is important to know its strength under normal work-day conditions.

The elasticity expresses the maximum elongation in centimeters which a Rayon thread, one meter long, has reached in the moment it breaks. Tensile strength and elongation usually are unequal and differ greatly according to quality. Both are influenced by the number of single filaments and

their twists. The determination of the tensile strength and elongation are carried out on specially-built apparatus (Fig. 178). The testers are driven either by hand, or by means of weights, or by water.

The length used in the tests is 500 cm. and the testers are built to take care of a maximum tensile strength of 1000 grams.

The elongation is expressed in millimeters and percentage. Before running these tests it is necessary to determine the humidity of the air by means of the hygrometer.

Twist and Uniformity of Rayon.—The coagulation of the cellulose expelled through a number of fine holes in the spinners produces several single threads which are parallel. These single threads are twisted either during the spinning process (pot spinning) or on special twisting machines, Fig. 179, and form the Rayon thread. The number of turns per meter is called the twist, which is determined on the twist counter.

The threads, one meter long, are fastened on both poles with equal spring pressure. The thread is now turned in the opposite direc-

tion of its twist until the single threads are parallel. This is determined by sliding a needle within the thread and the point is reached when the needle passes the whole length with-

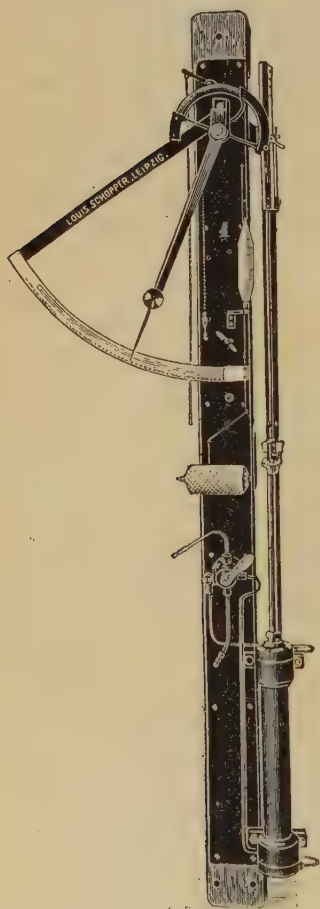


FIG. 178. Apparatus for Testing Strength and Elasticity, Hydraulic Drive (Schopper, Leipzig).

out any encountering resistance. The device registers the numbers of turns made, and this is the twist per meter.

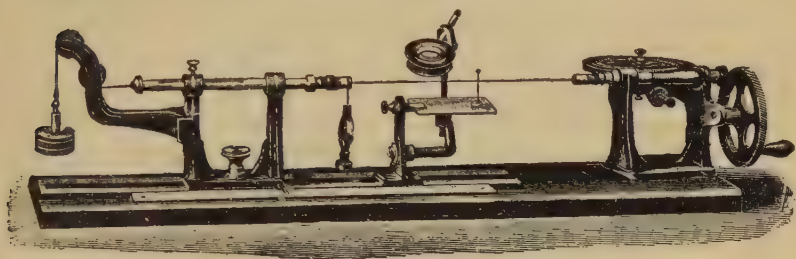


FIG. 179. Twist Counter (Schopper, Leipzig).

Tests for Uniformity and Impurity.—The uniformity and purity of the threads is tested on the uniformity tester (Fig. 180).

The threads are wound on a black paper board under

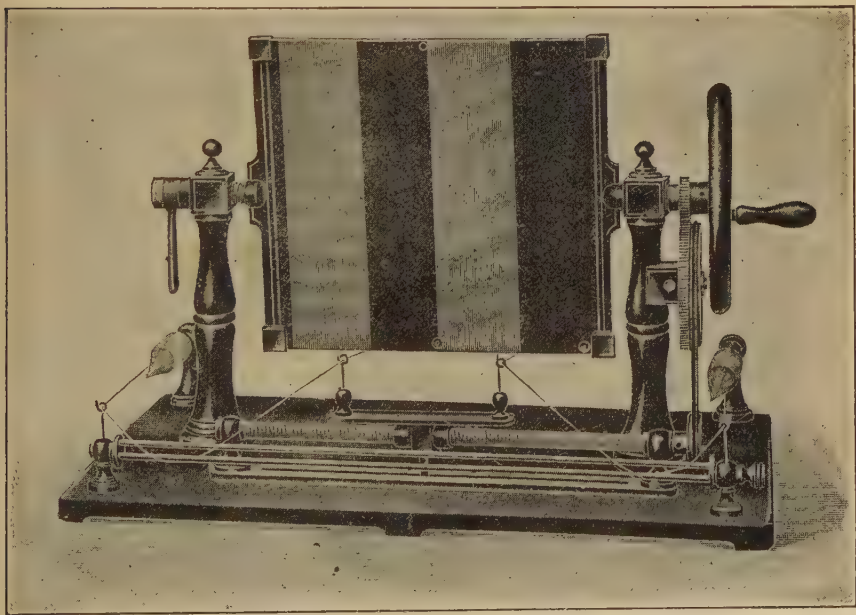


FIG. 180. Inspection Apparatus for Uniformity and Purity.

equal tension. The dark background allows the eye to perceive the slightest unevenness or impurity.

RAYON STANDARDS

The following report was presented by sub-committee XV of the Rayon Committee D-13 through its Chairman A. M. Terring, at the Greenville, N. C. meeting in October, 1925. Its draft is tentative but it will no doubt form the basis of future specifications:

DEFINITIONS

I. GENERAL

Rayon (formerly known as artificial silk). The generic name of filaments made from various solutions of modified cellulose by pressing or drawing the cellulose solution through an orifice, and solidifying it in the form of a filament, or filaments, by means of some precipitating medium. Rayon yarns are composed of more than one continuous Rayon filament. Spun Rayon is yarn made from cut Rayon filaments, the cut filaments being twisted and drawn out into a yarn by usual spinning processes.

2. CLASSIFICATION

Nitro-cellulose (Chardonnet), the name for filaments composed of a regenerated or denitrated cellulose which has been coagulated or solidified from a solution of nitrated cellulose.

Viscose, the name for filaments composed of a regenerated cellulose which has been coagulated or solidified from a solution of cellulose zanthate.

Cupra-ammonium, the name for filaments composed of a regenerated cellulose which has been coagulated or solidified from a solution of cellulose in ammoniacal copper oxide.

Cellulose-acetate, the name for filaments composed of an acetic ester of cellulose which has been coagulated or solidified from its solution.

3. IDENTIFICATION

Burning Tests to Distinguish Cellulose-acetate from All Other Rayons

(a) Viscose, nitro-cellulose and cupra-ammonium Rayon all burn like cotton, that is, with no odor and leaving very little ash.

(b) Cellulose-acetate Rayons burn more slowly than other Rayons and harden at once into a brittle substance globular in appearance.

Chemical Tests

Cellulose-acetate is readily soluble in pure acetone in concentrations of not over 1 per cent. This serves as a means of differentiating from other Rayons which are insoluble in this solution.

Tolerances

Size of Yarn Number (Denier)

The denier of a yarn is the weight in grams of 1000 meters.

Rayon Yarn.—The average size of each case of skeins, tubes, spools, cops, pirns, cones, or a beam warp of yarn in the singles, either bleached or unbleached, as found by test, shall not vary more than 5 per cent above or below the specified size.

Spun Rayon Yarn.—The average size of each case of skeins, tubes, spools, cops, pirns, cones, or a beam warp of yarn in the singles, either bleached or unbleached, as found

by test, shall not vary more than 5 per cent above or below the specified size.

Twist and Direction of Twist

Direction of Twist.—The yarn shall be considered to have a right-hand or regular twist if, when it is held vertical, the spirals or twist are seen to incline upward in a right-hand direction, and a left-hand or reverse twist when the spirals or twist are seen to incline upwards in a left-hand direction. The average twist of each case of skeins, tubes, spools, cops, pirns, cones, or a beam warp of yarn in the singles, or plied, either bleached or unbleached, as found by test, shall not be less than the specified strength. Ultimate strength, or strength at the highest yield point, may be specified.

TEST METHODS

Size of Yarn Number (Denier)

A. PREFERRED METHOD

The number of denier shall be determined (except when the Rayon is on beams) from skeins which have been prepared and weighed in an atmosphere of 65 per cent Relative Humidity and 70° F., after the spools, cops, tubes, cones, skeins, or other packages from which the test skeins are to be reeled have been conditioned in this atmosphere for three hours when in skeins, and twelve hours when in any of the other forms.

Any reel having a perimeter of 112.5 cm. may be used (see note). For yarns in skein form, a speed of 100 to 150 R.P.M. shall be used. For yarns on spools, cops, tubes or cones, the yarn shall be drawn off over end and a speed of 200 to 300 R.P.M. of the reel shall be used. The tension on

the yarn shall not be heavier than is necessary to lay the yarn smoothly on the reel at the specified speed. The skeins shall be weighed separately on a balance which shall be accurate to .25 per cent of the average weight of one skein.

Two skeins of 200 turns each from each of 10 spools, cops, tubes, cones or skeins, from one case out of every 10 cases shall be made, and the average of these 20 tests shall be the size or denier. Rayon received on beams shall be tested as specified. The size or yarn number in deniers is calculated as follows:

$$\text{Size or Yarn No.} = \text{Wt. of 225 meter skein (gr's)} \times 40$$

The yardage per pound of Rayon of any given denier may be calculated by the following formula:

$$\text{Yards per lb. of Rayon} = \frac{4,464,528^*}{\text{Given denier}}$$

B. ALTERNATE METHOD

The winding and weighing of the skeins shall be carried out under prevailing atmospheric conditions, following in all other respects the procedure outlined in Method A. The results thus obtained shall be reduced to a common basis of standard moisture regain for the class of Rayon under test by the following formula:

For nitro-cellulose, Viscose and Cupra-ammonium Rayons:

Denier corrected to 11.5% moisture regain =

$$\frac{\text{Denier} \times 111.5\%}{(100\% + \text{actual percentage of regain})}$$

To determine the actual percentage of moisture regain present in the sizing skeins, two groups of three skeins each

* 4,464,528 represents yards per pound of one denier yarn.

shall be taken immediately after weighing and the weight of each group recorded. They shall then be placed in two separate baskets in a conditioning oven and dried to constant weight on a balance sensitive to 0.25 per cent of the average weight of one skein at 105° C.

110° C. (221° F. to 230° F.).—The moisture regain of each group shall then be computed as the percentage of the dry weight and the average of these two shall be the actual percentage of moisture regain in the sizing skeins.

NOTE: In a laboratory which is equipped for testing cotton yarns only, the skeins may be prepared on any reel having a perimeter of 1½ yards. Each skein must contain 200 ends as before. If a skein of this length is used the yarn number of denier must be calculated by means of the following formula:

If the weighing is made in grams:

$$\frac{\text{Wt. of 300-yd. skein (grams} \times 1.64)}{.05 \text{ gram per denier}} = \begin{matrix} \text{yard number} \\ \text{or denier} \end{matrix}$$

If the skeins are weighed in grains:

$$\frac{\text{Wt. of 300-yd. skein (grams} \times 1.64)}{.7716 \text{ grain (per denier)}} = \begin{matrix} \text{yard number} \\ \text{or denier} \end{matrix}$$

STRENGTH

A. PREFERRED METHOD

One skein from each of the ten spools, cops, tubes, cones or skeins drawn for a sample shall be prepared as described under size or yarn number. The number of turns in these strength skeins shall be as specified in Table 97. For sizes which require 200 ends, ten of the sizing skeins may be used if desired.

TABLE 97: NUMBER OF TURNS IN RAYON STRENGTH SKEINS.

Denier of Rayon	Number of Turns in Strength Skein
1- 50 Denier	400
51- 75 "	200
76-120 "	150
121-200 "	100
Over-200 "	50

After conditioning for at least three hours in an atmosphere of 65 per cent Relative Humidity and 70° F. these ten skeins shall be separately broken on an automatic power yarn tester of inclination balanced type of 25 Kg. (55 lbs.) or 50 Kg. (110 lbs.) capacities. The lower capacity shall be used until the swing of the pendulum exceeds an angle of 45 degrees from the vertical. When yarns break above this mark the higher capacity of testing machine shall be used. The machine shall be equipped with an automatic charting device to record stretch at any load. Any tendency to friction, back lash or play in the recording device, lower jaw or screw, shall be overcome as far as practicable by counter balancing.

Jaws.—Clamps for holding the 200-end test skein shall consist of flat metallic jaws. These shall be covered with one layer of rubber tire tape which shall press directly against the specimen. One gripping surface shall be hinged or swiveled and the other shall be rigidly connected to the frame of the jaw. The pressure between the jaws shall be secured by any suitable mechanical device so constructed as to grip the yarns firmly before the testing load is applied and prevent visible slippage during the progress of the test.

The initial distance between jaws shall be 10 cm. (4"). The skein to be tested shall first be clamped in the upper jaws, spread out evenly so that the ends are parallel, forming a ribbon approximately $\frac{3}{8}$ " to $\frac{3}{4}$ " wide. The Rayon is then

drawn down through the lower jaws and spread out to make a band of equal width, pulled just taut and clamped.

Speed.—The pulling jaw shall travel at a speed of 6" per minute. One test shall be made on each of the 10 skeins and the average of these 10 tests shall be the strength.

B. ALTERNATE METHOD

Five single strands from each of 10 spools, cops, tubes, cones or skeins, shall be broken after conditioning the skeins for three hours and any other form of package for 12 hours in an atmosphere of 65 per cent Relative Humidity and 70° F. A single strand tester of proper capacity with the jaws set 10 inches between grips and having a speed of pulling jaw of 12 inches per minute, shall be used. The average of 50 tests shall be the ultimate strength.

Twist.—The twist shall be determined on any standard twist tester with jaws set 10 inches apart. The yarn shall be clamped in the jaws under a definite tension by attaching weights. The tension to be used shall approximate a value to be determined by the following formula:

$$\text{Tension in grams} = \frac{\text{Specified Denier}}{30}$$

Example: The tension for 150 denier Rayon would be:

$$\frac{150}{30} = 5 \text{ grams}$$

Two tests, from each of five spools, cops, tubes, cones or skeins, shall be made and the average of these 10 tests calculated to turns per inch shall be the twist.

Moisture Regain.—The standard moisture regain of nitro-cellulose, viscose and cupra-ammonium Rayons shall be 11.5

TABLE 98.—REACTIONS OF NATURAL SILK AND RAYON

Reagent	Nitro Rayon	Cupra Rayon	Viscose Rayon	Acetate Rayon	Natural Silk	Cotton	Wool	Linon
Water	Swells up			Slight swelling	No change	No change	No change	No change
Ignition	No odor, burns quickly, ash very small	No odor, burns quickly, leaves very slight ash	No odor, burns less quickly	Disagreeable odor, black residue	Odor of burnt feathers, black residue	No odor, burns quickly, small amount of ash	Burns with odor of burned feathers, black residue	No odor, burns slowly with small amount of ash
Reaction of ignition gases with litmus	Acid	Acid	Acid	Acid	Alkaline	Acid	Alkaline	Acid
Iodine and sulfuric acid	Violet blue, strong swelling	Pure blue, strong swelling	Pure blue, strong swelling	Yellow	Yellow	Swells and turns blue	Swells and turns blue	Swells and turns blue
Cold concentrated sulfuric acid	Dissolves quickly	Dissolves slowly	Dissolves quickly	Dissolves slowly	Dissolves quickly	Dissolves quickly	Does not dissolve unless heated	Dissolves quickly
Acetic acid	No action	No action	No action	Dissolves quickly	No action	Dissolves slowly	No effect	Dissolves slowly
Caustic potash (40%)	Swells without dissolving, liquid yellow			Swells greatly, but does not dissolve	Dissolves without color	Dissolves quickly, giving yellowish solution	Dissolves slowly	Dissolves quickly, giving brownish solution
Ammoniacal copper solution	Swells quickly and dissolves slowly	Swells slowly and dissolves slowly	Swells and slowly dissolves	Slight swelling, but does not dissolve	Fibroine dissolves, sericine insoluble, much wrinkled up	Dissolves blue solution		Bluish color, some swelling

per cent of the dry weight. The standard moisture regain of cellulose-acetate Rayons shall be 6.5 per cent of the dry weight.

To standardize to the above specifications and tests should be the aim of all Rayon producers. This will require the co-operation of both producers and consumers. The need for standardization both of specifications and test methods is vital, especially in view of the rapid Rayon development in the past few years. Specifications are, of course, valueless unless they represent possibilities in daily mill routine and it is hoped that the proper co-operation of producers and consumers will soon reduce these standards to practical value.

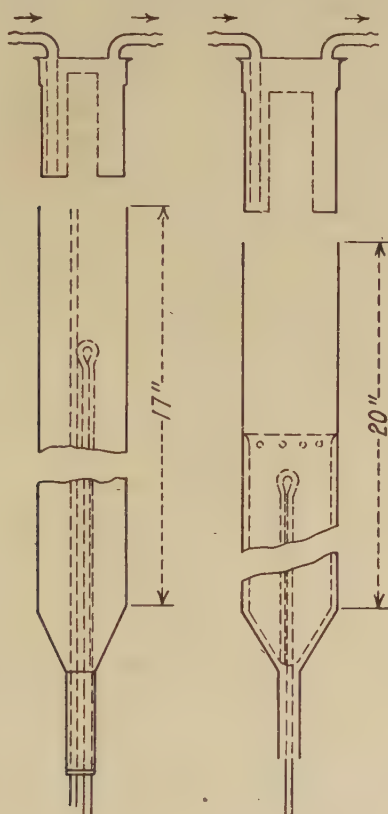
CONTROL TESTS FOR VISCOSE PROCESS

Testing the Cotton.—The cotton used in the Viscose process is mostly of the cheap grade known as linters. To control the cotton for the Viscose process it is tested for moisture fat, copper number, gummy matter, alpha, beta and gamma cellulose.

Determination of Moisture.—Dry the cotton from 4 to 6 hours at 105 degrees Centigrade and figure the loss of its weight as water. Repeat the drying until constancy of the weight has been reached.

Determination of Fat and Resin.—The contents of fats and resins are determined by extractions with ether-alcohol or chloroform. The cotton is first air-dried. The extraction is carried out with a Soxhlet (Fig. 182) for a Graefe extractor. Extract first with ether and then with alcohol. Six hours' extraction are usually required for a complete removal of the fats and resins. After the extraction, remove the thimble from the extractor and distill most of the solvent into

the same. The flask with the extract substance and the rest of the solvent is taken off the extractor, the solvent evaporated on the water-bath, then the contents of the flask are dried at 90 degrees Centigrade and weighed after cooling.



Ordinary Type Soxhlet.

Hot Type Soxhlet.

FIG. 181. Soxhlet Apparatus for Determining Fat in Cotton.

Determination of Copper Number.—This determination gives us the amount of hydro- as well as the oxy-cellulose present, and it is determined by the amount of cuprous oxide

which is formed from Fehling solution through the reducing action of the hydro- and oxy-cellulose present in the cotton. The percentage of these derivatives of cellulose in the cotton should be small because they lower the strength of the finished product. The apparatus for this determination consists of a round flask (A) with wide neck of 1½ liters content (Fig. 182.

In the neck of the flask a condenser (B) is tightly fitted.

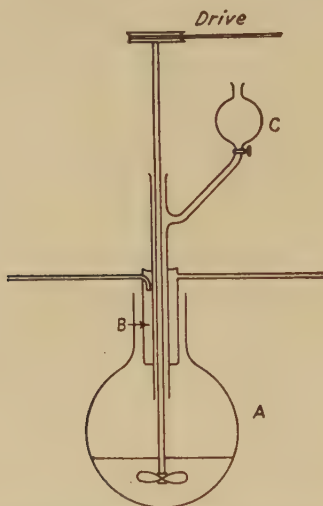


FIG. 182. Apparatus (Schwalbe) for Determining the Copper Number of Cellulose.

The condenser tube has a connection with a side tube (C) through which the reagents can be poured into the flask. Through the condenser tube a stirrer leads into the flask to keep the liquid agitated. Either a centrifugal stirrer or a glass stirrer is used. The latter is recommended because if loose cotton is used with the test it has the tendency to pack around the small balls of the centrifugal stirrer.

Fill the flask with about one liter of water, add a weighted

amount of the cotton and heat to boiling. At the same time heat 50 cc. of alkaline Seignette salt solution and 50 cc. of copper-sulphate solution in two Erlenmeyer flasks. When the liquids start to boil mix them then and pour the mixture into the flask with the boiling water; boil for 15 minutes and stir continuously during this period. Remove the burner, wash down the drops which adhere to the condenser and filter the contents of the flask on an alundum dish, using suction. Wash carefully with hot water until the copper test of the wash-water is negative. The filtrate contains the fibre material which is blue and the precipitate is cuprous oxide.

The determination of cuprous oxide is done in two ways: Dissolve the oxide as well as the blue copper compound with nitric acid $6\frac{1}{2}$ per cent and electrolyze the copper in the resulting solution. The second method is: Digest the precipitate with 100 cms. of a solution containing 50 grams of ferric-sulphate and 200 grams of concentrated sulphuric acid per liter. This solution dissolves only the cuprous oxide, and the formed ferro-sulphate corresponds to the amount of cuprous oxide present. The ferro-sulphate is then determined by titration with potassium permanganate. This gives the correct copper-number, while in the electrolytic method a small correction must be made on account of the dissolved blue copper compound. Formula for Fehling's solutions:

(1) Copper-sulphate cryst. c.p. 34.639 grams per 500 ml. of distilled water.

(2) 173 grams crys. c.p. Seignette-salt dissolved in 400 ml. distilled water. Add 100 ml. of caustic solution containing 500 grams caustic soda per liter.

Determination of Gummy Matter.—The gummy matter is a criterion of the impurities present in the cotton. They are mostly pentosanes, which are soluble in a 5 per cent solution of caustic soda. A weighed quantity of the cotton is treated

with a 5 per cent caustic soda solution and the gum is precipitated with acetic acid. The precipitate is filtered, dried and weighed.

Determination of Alpha, Beta and Gamma Cellulose.—Alpha cellulose is that modification of cellulose which takes part in the Rayon process. The other modifications of cellulose are dissolved, and not regenerated and therefore are lost during the process. The amounts present of beta and gamma cellulose should, therefore, be very small. Alpha cellulose is soluble in a caustic solution, but beta cellulose is precipitated by acetic acid while the gamma cellulose remains dissolved. On these facts their separation and determination depends. Ten grams of air-dried cellulose fiber are taken and rubbed to a paste with 50 cc. of 17.5 per cent caustic soda solution. After standing for a half hour this cellulose paste is transferred to an alundum crucible and washed with boiling water until free from alkali. Rinse with diluted acetic acid and then again with water. Dry at 100 degrees Centigrade and weigh. This residue is the alpha cellulose. Precipitate the filtrate with acetic acid. Filter dry and weigh the precipitate. This is the beta cellulose. The difference in weight between the cotton sample taken and the sum of the alpha and beta cellulose is the gamma cellulose.

Uniformity of Dyeing.—Another important property which cotton for the Viscose process must possess is its relation to the absorption of dyes. The absorption of dyes must be very even and uniform or else the cotton is not adapted for use.

Caustic Soda.—The strength of the caustic soda used for the Viscose process is determined by titration with normal acid, using phenolphthalein as indicator.

Carbon Bisulphide.—The carbon bisulphide must contain neither hydrogen sulphide nor benzene. No residue should remain on evaporation, or at least only a trace, on account

of small quantities of sulphur which might be present. Large amounts of sulphur would have a bad effect and should cause the rejection of the carbon bisulphide.

Viscosity.—The determinations of the viscosity serve to control the ripening process of the Viscose solution. The methods mostly used are as follows: Constant checking of the viscosity of the spinning solution is very important in order to keep it uniform so that threads of proper strength and size can be made.

The viscosimeter used is either of the tube type or of the orifice type. The tube type depends for its operation on the time taken by an air bubble to pass two fixed marks of a tube, or on the time taken by a small nickel ball to sink through a tube of the liquid. Time is measured by a stop watch. Viscosity determination must always be made at the same temperature. The orifice type of viscosimeter depends for its operation on the time taken by a given quantity of the solution to be tested in passing through an orifice of standard size. Temperatures must always be the same.

Coagulation.—The Viscose solution during ripening is also controlled by precipitating samples at different stages. The precipitation is accomplished by diluted organic acids or by a 10 per cent solution of ammonium chloride. The precipitated cellulose-xanthate is tested as to its solubility in water.

Coagulating or Neutralizing Bath.—The strength of the coagulating bath is checked with the hydrometer. Free acid is titrated with caustic solution of known strength. The sugar content is determined as follows: The caustic soda is determined by titrating a measured or weighed quantity with normal acid solution using phenolphthalein as an indicator. The amount of the sugars present is determined by boiling a measured sample with an excess of standard potassium permanganate solution. The sugar is titrated with oxalic acid.

CONTROL TESTS FOR NITRO-CELLULOSE PROCESS

Chemical Control of Cotton.—The cotton used for the manufacture of nitro-Rayon must be long-stapled, and must not be overbleached. Tests are run to determine moisture, fat, and copper number.

Determination of Moisture.—Dry the cotton from 4 to 6 hours at 105 degrees Centigrade and figure the loss of its weight as water. Repeat the drying until constancy of the weight has been reached.

Determination of Fat and Resin.—The contents of fats and resins in the cotton, to be used in the nitro-cellulose process, are determined in the same way as in the Viscose process.

Determination of Copper Number.—This determination of the copper number for the nitro-cellulose process follows the same method as in the case of the Viscose process.

Chemical Control of the Nitration.—The nitration acid is a mixture of nitric and sulphuric in the proportion necessary for the nitration of the cellulose. After nitration, the acid mixture is composed mostly of sulphuric, some nitric, and a small amount of nitrous acid, as well as a small percentage of organic substances formed and dissolved during the process. The spent acid is regenerated by the addition of an acid mixture of the proper strength or by separate additions of nitric and sulphuric acids. The strength of the nitrating, spent and regenerating acids are determined as follows:

(1) Total acidity: Measure an excess of normal caustic soda solution into a beaker, add a weighed quantity of the acids and titrate back the excess of the caustic soda solution with normal acid solution, using fluorescein as indicator.

(2) Determination of the total nitrogen in the acids— if a nitrate, a solution of a nitrate or a mixture, both are shaken with mercury and an excess of sulphuric acid

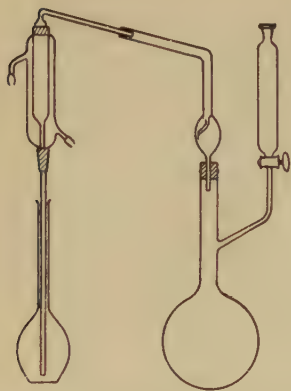


FIG. 183. Apparatus for Determining Nitrogen in Cotton.

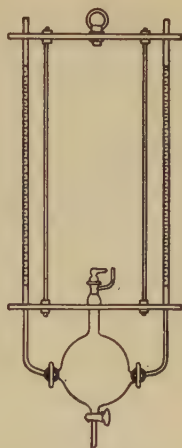
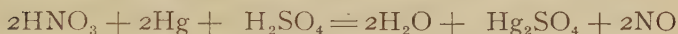
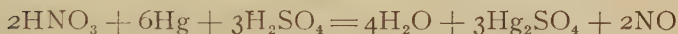


FIG. 184. Accurate Type of Titration Apparatus.

and all of the nitrogen is set free as nitric oxide according to the reactions:



From the volume of the nitric oxide liberated, the weight of the nitrogen containing acids or salts is computed. The analysis is best performed in a Lunge nitrometer. The Lunge nitrometer is simply a Bunte burette in which the lower stopcock is omitted and the lower end is connected with a leveling tube containing mercury. By raising the latter, completely fill the nitrometer with mercury and then close the two-way cock under the funnel. Place a weighed amount of the solution which is to be analyzed in the funnel, lower the leveling tube, and introduce the solution into the nitrometer by carefully opening the cock.

Wash out the funnel several times with a few cubic centimeters of concentrated sulphuric acid. Now remove the

measuring tube (decomposition tube) from the frame, turn several times to a nearly horizontal position and then quickly change to a vertical position. In this way the mercury becomes intimately mixed with acid and the nitrates, and the decomposition of the latter at once begins. Continue mixing for one to two minutes until there seems to be no further increase in the volume of the liberated gas. Now level the mercury in the measuring and leveling tube, but place the mercury a little higher in the leveling tube to compensate for the height of the acid layer in the measuring tube. Allow 1 mm. of mercury to $6\frac{1}{2}$ mm. of acid. After a few minutes read off the volume of the nitric oxide, and note the temperature as well as the barometer reading.

Another method frequently used to determine the mixed acids is based on the reduction of nitrates, and nitrates to ammonia which is distilled into a flask containing a measured quantity of sulphuric acid for the absorption of the ammonia. The reduction is performed, after the neutralization of the mixed acids, by means of a copper-magnesium alloy in presence of magnesium chloride and the ammonia is computed from the amount of normal sulphuric acid which was used up for the absorption of the ammonia. This is a modification of the familiar Kjeldahl method.

Determination of Nitrous Acid and Organic Matter.—To determine the total organic matter and nitrous acid add a weighed amount of the acids to a flask containing a measured excess of half-normal potassium permanganate solution, heat to boiling, and continue boiling for five minutes. The nitrous acid and the organic matter are oxidized and an equivalent amount of the permanganate solution will be used up. Cool the solution in the flask, add a few crystals of potassium iodide and titrate the iodine freed by the excess of permanganate with a solution of half-normal sodium-thiosul-

phate. The amount of permanganate solution used for the oxidation can then be calculated.

To determine the easily-oxidizable organic matter and nitrous acid measure a certain quantity of the acids into a beaker and titrate with permanganate solution at a temperature of 40 to 45 degrees Celsius. To determine the total organic matter only, dilute a weighed quantity of the acids, add a few grams of ammonium sulphate and boil the solution for several minutes to expel the nitrous acid. Afterwards add an excessive amount of permanganate solution, boil for five more minutes, cool, add potassium-iodide and titrate with thiosulphate solution to determine the excess of the permanganate solution.

To Estimate the Nitrous Acid.—Take a measured quantity of the acids, introduce carbon-dioxide gas, then add a solution of potassium-iodide. The nitrous acid frees an equivalent amount of iodine, which is titrated with a standard sodium-thiosulphate solution.

The Chemical Control of Nitro-cellulose.—Control determinations comprise the estimation of moisture, ash and nitrogen, and also the solubility in ether-alcohol and the viscosity.

Moisture.—A sample of nitro-cellulose is powdered, sifted and weighed. The sample is then dried in a current of dry air at 40 to 50 degrees Centigrade or it is dried in *vacuo* over calcium-chloride until the weight is constant. The loss in weight is moisture.

Ash.—Five grams of dry nitrocellulose are ashed in a platinum dish at the lowest possible temperature. This ash is then dissolved in a solution of ammonium carbonate. Evaporate to dryness and heat to about 200 degrees Centigrade. This operation is repeated until the weight of the ash is constant.

Nitrogen.—The principle of this determination is the same

as that for the determination of nitrogen in the nitration acids. A sample of nitro-cellulose is oxidized with chronic and concentrated sulphuric acid. This operation converts the nitrogen peroxide to N_2O_4 and the organic matter to carbon dioxide (CO_2). After oxidation is complete a few cubic centimeters of mercury and sulphuric acid are added and the mixture is well shaken. The higher oxides of nitrogen are thus reduced to nitric oxide. This decomposition must be carried out in a special flask so that the resulting mixture of nitric oxide and carbon-dioxide can be transferred to the nitrometer. Caustic soda is used to absorb the carbon-dioxide, then the tubes are leveled and the volume of the nitric oxide remaining is read off. This volume has to be corrected to the standard conditions of temperature and pressure. The nitro-cellulose for Rayon manufacture should have about 11.5 per cent nitrogen.

Solubility in Ether-Alcohol.—Three grams of nitro-cellulose are digested with 50 cc. of absolute alcohol for 40 minutes in a 150-cc. graduated cylinder. Then 100 cc. of ether are added and the mixture is shaken frequently for a period of twelve hours. The mixture is allowed to settle and 50 cc. of this solution are taken and evaporated to dryness in a platinum dish. The weight of the residue is taken as soluble nitro-cellulose. This determination is further checked by taking another portion of the solution, precipitating the nitro-cellulose with water, filtering on a weighed filter, drying the precipitate at 40 degrees and washing. This precipitate is re-dissolved in alcohol-ether, re-precipitated, filtered and weighed again.

Viscosity.—Determining the viscosity of a spinning solution is one of the most important checks because, by it, the value of the spinning solution is judged for use. The viscosity of the solution must always be about the same value or else tearing and unevenness of the threads results. The viscosimeter is quite simple and consists usually of a long nar-

row tube of glass having two marks, one near each end. The tube is filled with the solution leaving a small air space. If the tube is turned upside down an air bubble will rise to the new surface and the time is measured which is required for the bubble to pass from the first mark to the second mark. Another method uses a small nickel ball which is dropped into the tube and the elapsed time is measured which is required for the ball to pass two given marks. Still another method is to measure the time of out-flow from a standard orifice. Viscosity must always be determined at the same temperature.

Uniformity of Nitration.—Fibers which are properly nitrated give bluish or grey colors under the polariscope, while incomplete nitration can be recognized by the presence of all the spectral lines.

Alcohol and Ether.—Both solvents should be free from acids and peroxides. Alcohol-ether mixtures are determined as follows:

10 cc. of the alcohol-ether mixture are poured into a glass-stoppered cylinder, 5 cc. of gasoline and 5 cc. of water are added, and the whole thoroughly shaken. After a few minutes a sharp layer is formed. The lower layer contains the alcohol and the water while the upper layer contains the ether and the gasoline. Assuming that the upper layer is 12 cc., lower 8 cc., then we have a mixture of 7 parts of ether and 3 parts of alcohol.

Percentage of Nitro-Cellulose in the Spinning Solution.—The amount of nitro-cellulose in the spinning solution is determined by running a weighed quantity into hot water. Filter the precipitated nitro-cellulose, dry and weigh.

Testing the Bleaching Liquor.—A certain quantity is pipetted into a flask, a solution of potassium-iodide is added, the freed iodine is titrated with standard sodium-thiosulphate solution.

Test for Stability of Nitro-Rayon.—A sample of nitro-Rayon is heated at 135 degrees Centigrade. The Rayon should stand this heating for at least seven to eight hours without showing any acid reaction. The presence of freed acid would be apparent from any carbonization caused on further heating.

CONTROL TESTS FOR CUPRA-AMMONIUM PROCESS

Testing the Cotton.—The chemical control of cotton is the same as for other Rayon processes when cotton is used as a raw material. However, the cotton for the cupra process can be a cheap grade and cotton linters are mostly used for the purpose. Tests must be run to determine moisture, fat and copper number.

Determination of Moisture.—Dry the cotton from four to six hours at 105° C. and figure the loss of its weight as water. Repeat the drying until constancy of the weight has been reached.

Determination of Fat and Resin.—The contents of fats and resins are determined in exactly the same way as in the case of the Viscose or nitro-cellulose processes.

Determination of Copper Number.—This determination is obtained in exactly the same manner as in the case of the Viscose or Nitro-cellulose processes.

Ammonia Determination.—Pipette several grams of the solution into a flask and titrate with normal sulphuric acid solution using methyl-red as indicator.

Cupra-Ammonium Solution; Tests for Ammonia and Copper.—Make the sample in a Dewar flask to retain the low temperature. This avoids the rapid decomposition which would otherwise occur. Take a weighed quantity and titrate with normal sulphuric acid to determine the amount of ammonia present. Run in enough acid until the blue solution is discolored, then add a few drops of methyl-red and titrate

to the end point. Another portion is titrated with a standardized solution of potassium cyanide. Add drop by drop until the blue color disappears.

Cupra-Ammonium Cellulose Solution.—Weigh off a sample into a flask and titrate the ammonia as above. During this titration the cellulose is precipitated in white flakes. The contents of the flask are filtered through a weighed Gooch crucible. The cellulose which remains in the crucible is washed until free from sulphuric acid. The crucible with the washed cellulose is dried for several hours in an electric oven. The drying is repeated until the weight is constant. Another method for determining cellulose is to precipitate the cellulose with phosphoric acid. Carbonates present must be removed first by boiling the solution for several minutes. Then add chromic acid which oxidizes the cellulose to carbon-oxide. Collect the evolved gas in a gas burette where its volume may be read. The copper in the cupra-ammonium cellulose solution is titrated with a standardized cyanide solution as mentioned above.

Testing the Coagulating Solution.—The caustic soda is determined by titrating a measured or weighed quantity with normal acid solution using phenolphthalein as an indicator. The amount of the sugars present is determined by boiling a measured sample with an excess of standard potassium permanganate solution. The sugar is titrated with oxalic acid.

Viscosity.—Constant checking of the necessity of the spinning solution is very important in order to keep it uniform so that threads of proper strength and size can be made. The viscosimeter used is either of the tube type or of the orifice type. The tube type depends for its operation on the time taken by an air bubble to pass two fixed marks of a tube or on the time taken by a small nickel ball to sink through a tube of the liquid.

Time is measured by a stop watch. Viscosity determina-

tion must always be made at the same temperature. The orifice type of viscosimeter depends for its operation on the time taken by a given quantity of the solution to be tested in passing through an orifice of standard size. Temperatures must always be the same.

CONTROL TESTS FOR THE CELLULOSE-ACETATE PROCESS

Testing the Cotton.—The quality of the cotton is tested in the usual ways as given in the preceding processes.

Determination of the Acetic Acid.—Saponify the cellulose compound with cold sulphuric acid (50 per cent) for 24 hours, then distill the freed acetic acid with steam. The receptacle contains all the acetic acid and is titrated with a standardized caustic soda solution.

Solubility.—The solubility of the cellulose-acetate in chloroform points to a highly acetylated cellulose while the lower acetylated cellulose is insoluble in chloroform, but soluble in acetone.

Viscosity.—This is also determined in the usual way, as previously described.

CHAPTER XIX

PATENTS

PATENTS

THE patent literature on Rayon processes, machinery and allied equipment is voluminous. For the purposes of the present volume little more can be done than to cite the patents. These citations at least will suffice to show what an immense amount of work has been done in the field and with what care the various allowances have to be reviewed. As is true in every other field of endeavor many claims are granted which have no commercial applicability whatsoever and it requires a careful sifting and trying to separate the wheat from the chaff. The following patents are cited as having been of value in the establishment and promotion of the Rayon industry. These can be conveniently grouped by processes and again sub-divided as to their point of application in the process.

The titles of patents and their brief description have, of necessity, been retained as published by the patent offices of the different countries. It will thus be noted that the term artificial silk prevails here in lieu of the term Rayon which is generally adopted in the United States.

THE NITROCELLULOSE GROUP

General processes and devices for the manufacture of nitrocellulose Rayon:

CHARDONNET—French Patent No. 165349, Nov. 17, 1884, covers the manufacture of artificial silk from collodion with or without the addition of dyes.

CHARDONNET—German Patent No. 46125, Class 12, granted Feb. 4, 1888. Covers the process for the partial denitration of collodion fibres and their subsequent dyeing.

CHARDONNET—German Patent No. 56331, granted Feb. 6, 1890, Class 29. This is a very important patent and covers the spinning machine in all its essentials.

CHARDONNET—German Patent No. 81599, Class 29, granted Oct. 11, 1893. Covers the process of manufacturing fibres from a hydrated (25–30%) nitrocellulose.

CHARDONNET—German Patent No. 64031, Class 78, granted Oct. 30, 1891. Covers process for pretreating cellulose in order to improve its solubility and spinning qualities.

GERARD—German Patent No. 40373, Class 22, granted Sept. 14, 1886. This patent is of interest in that it covers the formation of threads, *plates* or *any formed objects* from any viscous solution many of which are specifically named but excepting tri-nitrocellulose in ether-alcohol but claiming for other solvents.

DU VIVIER—French Patents, 195654, granted Jan. 26, 1889 and several others following. Covers a spinning solution made by dissolving nitrocellulose in glacial acetic acid. Also a method of spinning and a coagulating bath composed of phenol and mercuric chloride; also a bath for reducing inflammability consisting of aluminum salts, and a lustre producing bath consisting of dissolved albumen. The patent also covers a special nitrating apparatus.

LEHNER—French Patent, 221901, May 25, 1892. This covers a process for making a spinning solution by pretreating cellulose with copper-ammonia solution, subsequently nitrating and dissolving the nitrocellulose in wood alcohol with the addition of linseed oil, kopal, sandarak, in sulphuric ether. It also covers the use of sodium acetate and ammonium acetate dissolved in alcohol for the purposes of reducing inflammability. Another point covered is a recovery system for solvents.

LEHNER—Swiss Patent No. 3740, granted in 1890. This covers a special spinning solution and also improvements in the

spinning machine. Also covers the treatment of fibres in alkali hydrosulphides in the presence of magnesium and ammonium salts.

PETIT—British Patent, 15343—1900. Covers additions of dissolved rubber and various tin salts to the nitrocellulose solution in order to reduce the inflammability of the resulting threads.

LA GRANGE—Swiss Patent, 22680. This also covers the addition of dissolved rubber, and tin chloride to a nitrocellulose spinning solution in order to reduce inflammability.

VALETTE—French Patent, 344660. Covers the process of partially denitrating the nitrocellulose, then dissolving in various solvents with the addition of ammonium nitrite. This treatment was claimed to make the nitrocellulose threads non-explosive and fire-resistant.

TURGARD—French Patent, 344845. This covers the addition of resin oil and albumin to the nitrocellulose spinning solution in order to reduce the tendency of filaments to stick together.

CAZENEUVE—French Patent, 346693. This covers the use of acetone as solvent for nitrocellulose. Also *denitration before spinning* by the use of metallic hydrosulphides or sulphides.

CAZENEUVE—French Patent, 350723. Covers the pretreatment of acetone in order to improve the resulting spinning solution. Also the use of ammonium hydrosulphide to improve lustre and strength.

GORRAND—British Patent, 6166—1906. This covers the use of a mixture of acetone, amyl alcohol and acetic anhydride as solvent for nitrocellulose in preparing a spinning solution.

GERMAIN—French Patent, 355016. This covers the addition of a rubber solution to an acetone spinning solution in order to improve lustre, elasticity and strength.

GERMAIN—French Patent, 360395. Covers the addition of celluloid waste and powdered barium sulphate to nitrocellulose dissolved in acetone, to improve lustre and wet strength. The patent also covers the use of sulphuric acid as coagulating bath. This is claimed to eliminate the necessity for denitration.

CAHEN—French Patent, 434868. Covers the addition of aluminum salts, sodium formate, nitric acid and water to the nitro-

cellulose spinning solution, in order to improve spinning qualities, strength, etc.

SHRAGER AND LANCE—German Patent, 271747, Class 29b, April 14, 1912. Covers the addition of metal resins especially of zinc or magnesium to the nitrocellulose spinning solution in order to reduce inflammability and in order to make the threads water resistant.

SOCIÉTÉ LA SETAID—French Patent, 478461. Covers an apparatus for making silk-like threads by simple gravitational pressure, the thread dropping on a rotating gathering disc for the purpose of forming a cocoon. (Can this have been the germ of the idea of the Topham centrifugal box?)

KAZUTA KISHI—French Patent, 473986. This covers the addition of oil (obtained from silk worms in the pupa state) to the nitrocellulose solution for the purpose of increasing lustre, strength and water resistance.

Concerning the pretreatment of cellulose previous to nitration, methods of producing, treating and handling nitrocellulose, the following patents are of interest:

BERL—German Patent, 199885, Class 29b, granted April 5, 1907. Covers a system of pretreating cellulose by exposing same to the action of acid, free gases and superheated steam.

VEREINIGTE KUNSTSEIDE FABRIK, A.G.—French Patent, 455011. Covers the treatment of regularly nitrated cellulose with cold spent acid for the purpose of making the nitration more uniform.

SOCIÉTÉ ANONYME DE PRODUITS CHIMIQUES DE DROOGENBOSCH—British Patent, 5076—1901. Covers the treatment of washed nitrocellulose in heated ammonia-laden air in order to completely neutralize any acids present which might have a deleterious effect on subsequent operations due to attacking metal parts, etc.

J. DOUGE—British Patent, 2476—1902. Covers the treatment of nitrocellulose in air of about 10 per cent water content until ready for solution in order to prevent spontaneous combustion. Also to treat with alkaline solutions in order to neutralize excess acid.

- STOERK—German Patent, 169931, Class 29b, granted Nov. 29, 1902. Process for spinning filaments from a hydrated nitrocellulose containing 12 per cent to 20 per cent of water.
- LA CROIX—French Patent, 351265. Covers the solubility of a hydrated nitrocellulose containing 35 per cent to 45 per cent of water, claiming that less ether is required to produce a spinning solution.
- DIETL—French Patent, 356323. Covers the use of a hydrated cellulose of 33 per cent to 38 per cent water content claiming to result in filaments which do not stick when they are gathered in the bobbin.
- KUNSTFADEN GESEL m.b.h.—French Patent, 371544. Covers the use of a hydrated cellulose of 20 per cent to 25 per cent water content, claiming superior solubility, ease of filtering, and regularity of filament production. Also simplification of denitration.
- CHANDELON—German Patent, Class 78c, granted May 17, 1911. To cover the increase in solubility of nitrocellulose under heat and pressure and using a small addition of mineral acid.

Concerning the preparation of the nitrocellulose solution, specific solvents and filtration, the following patents are worthy of note:

- BRONNERT & SCHLUMBERGER—German Patent, 99009, Class 22, Nov. 19, 1895. Covers the preparation of a nitrocellulose solution using ethyl alcohol after impregnating the nitrocellulose with chlorides, lactates or acetates.
- DUQUESNOY—German Patent, 135316, Class 29b, issued May 15, 1900. Covers the solubility of nitrocellulose in a mixture of acetone, acetic acid and annyl alcohol.
- FABRIQUE DE SOIE ARTIFICIELLE DE TUBIZE—French Patent, 361690. Covers an improved process for producing lustrous threads from collodium by treating nitrocellulose either dry or in solution with oxyacids of the fatty acid series.
- HUWART—French Patent, 383555. Covers the use of esters of the fatty acid series or their derivations to promote the solubility of nitrocellulose in alcohol.
- SAUVERZAC—French Patent, 402950. Covers the use of alcoholic

solutions of metallic chlorides in increasing the solubility of nitrocellulose in any of the usual solvents.

STREHLENERT—British Patent, 22540—1896. Covers the addition of the aldehydes to nitrocellulose solutions, claiming to increase the resistance of the threads to water.

A. LUMIERE ET SES FILS—German Patent, 171752, Class 29b, April 30, 1905. Covers the solution of nitrocellulose in a large excess of ether-alcohol solvent. This excess is reduced by heating whereby the alcohol-ether is recovered and at the same time the solution is freed from air bubbles.

DUCLAUX—French Patent, 439721. Covers the use of methyl and ethyl formate to promote the solubility of nitrocellulose.

MASSMAN—German Patent, 250421, Class 22g, issued April 13, 1910. Covers the use of mixtures of alcohol and benzol and their homologues as solvents for nitrocellulose.

A. LUMIERE ET SES FILS—French Patent, 361329, issued about April, 1905. Covers a filter press of special construction suitable for collodium solutions.

MAURICE DEINS—German Patent, 245837, Class 12d, issued Aug. 6, 1910. Covers a filter medium in the form of a renewable cone placed in a feed line with shut-off *cocks* one each side. Perhaps the forerunner of the modern "candle" filter.

The following processes, methods and devices are set forth in patents covering the act of thread formation, spinning of nitrocellulose solutions, spooling and twisting:

MERZ—Swiss Patent, 4449. Covers a multiorifice spinnerette and its operation and control.

ÖBERLE AND NEWBOLD—French Patent, 258287. Covers the use of reduced pressures on the spinnerette in thread production as against positive pressures on the spinning solution.

BREUER—German Patent, 55293, Class 29, issued Jan. 26, 1890. Covers device and method for generating filaments by cutting them spirally from cylinders of hardened collodium.

CRISPIN—French Patent, 342077. Covers a multiorifice spinnerette consisting of a platinum disc fastened to a flanged glass tube with a rubber ring.

- A. LUMIERE ET SES FILS—German Patent, 168173, Class 29b, issued April 30, 1905. Covers the use of solvents of nitrocellulose, especially amyl acetate, for use as pressure medium on the spinning solution instead of water.
- A. LUMIERE ET SES FILS—German Patent, 200265, Class 29b, issued Dec. 28, 1906. Covers a tubular device through which the generating thread is dropped in an atmosphere of alcohol vapor to prevent the too-rapid hardening of the filament.
- DEMARAIS, MORANE AND DEINS—German Patent, 197167, Class 29a, issued March 29, 1905. Covers a device for regulating the pressure of collodium solutions during filtering and spinning.
- MORANE—French Patent, 410267. Covers a precision spinning machine. Perhaps the forerunner of the modern pump.
- DEINS—French Patent, 423934. Covers a continuous spinning machine embodying some of the principles of the modern frame.
- DEINS—German Patent, 233627, Class 76d, issued Dec. 28, 1910. Covers an automatic weighing device for sorting spools covered with Rayon.
- BOULLIER—French Patent, 368190. Covers process for spinning filaments of nitrocellulose from acetone and acetic-ether solutions at temperatures of 30° to 40° C.
- BOULLIER & LAFARS—German Patent, 210867, Class 29a, issued July 14, 1908. Covers a process of spinning any collodium solution and exposing generated threads to radiant heat.
- BONILLOT—French Patent, 373947. Covers a process for gathering nitrocellulose filaments on a heated cylinder, enclosed in a chamber to facilitate solvent recovery.
- VITTENET—French Patent, 386109. Covers a process for improving the lustre and appearance of nitrocellulose filaments by controlling the temperature and humidity of the air in the generating chamber.
- CORDONNIER-WIBAUX—French Patent, 401343. Covers a method of heat control in the chamber through which the generated nitrocellulose filaments pass.
- FIVE—German Patent, 200824, Class 29a, issued Feb. 19, 1907. Covers an adjustable filament guide to adjust thread gathering tension.
- SOCIÉTÉ ANONYME DES CELLULOSES PLANCHON—German Patent,

- 219128, Class 29a, issued July 28, 1908. Covers a rotating spinnerette.
- KRAFFT—German Patent, 186277, Class 29a, issued Mar. 1, 1906. Covers a system of gathering nitrocellulose filaments by passing over and around a reel before winding on the bobbin.
- A. LUMIERE ET SES FILS—German Patent, 173012, Class 29a, issued April 30, 1905. Covers a revolver-like magazine of bobbins for gathering filaments.
- SAUVERZAC—French Patent, 415060. Covers a device for twisting the filaments as they are gathered.
- LOWE—German Patent, 234927, Class 29a, issued Oct. 10, 1908. Covers a system of giving nitrocellulose filaments greater travel in order to completely harden them and concentrate solvent recovery.
- LOEWE—French Patent, 403243. Covers an improvement in the spinning chamber.
- LOEWE—German Patent, 238160, Class 29a, issued Jan. 21, 1909. Covers an improvement in spinning practice in that a storage chamber is provided ahead of the spinnerettes.
- CAHEN—French Patent, 434869. Covers a system of spinning with multiorifice spinnerettes and without pressure.
- DEINS—German Patent, 254801, Class 29a, issued Feb. 23, 1912. Covers a manifold for holding any desired number of spinnerettes.
- DEINS—German Patent, 277154, Class 29a, issued May 28, 1913. Covers a system of spinning in vacuo or under reduced pressure.
- CHARDONNET—German Patent, 320908, Class 29a, issued July 27, 1915. Covers all details of the modern collodium solution spinning frame; many of its claims are still in force.
- BERL AND ISLER—(Tubize) German Patent, 273936, Class 29b, issued June 17, 1913. Covers a coagulating bath for nitrocellulose threads consisting of alcohol and alcohol mixtures at temperatures below the boiling point of ether.
- FABRIQUE DE SOIE ART. D'OUBURG AND DEINS—Covers a circular spinnerette carrier which permits a succession of spinnerettes to be brought into service from the feed line.

The following patents cover processes and devices for de-

nitrating, fireproofing nitro-Rayon and various other treatment processes:

TURGARD—French Patent, 218759. Covers the use of silver sulphide and others for the prevention of sulphur precipitation during nitration.

KNÖPFLE—German Patent, 88556, Class 29, issued Mar. 29, 1894. Covers the use of formaldehyde as a denitrating agent for nitrocellulose filaments.

RICHTER—German Patent, 125392, Class 29b, issued Feb. 1, 1901. Covers the use of oxy-salts of metals in the denitrating bath.

RICHTER—German Patent, 139442, Class 29b, issued June 6, 1901. Covers the use of oxy-salts of copper in ammoniacal solution in the denitrating bath.

RICHTER—German Patent, 139899, Class 29b, issued July 30, 1901. Covers the use of oxy-chloride of copper in solutions of alkali and alkaline earth chlorides in the denitrating bath.

COMPAGNIE DE LA SOIE DE BEAULIEU—German Patent, 217128, issued July 31, 1907. Covers apparatus and process of denitrating wound nitrocellulose filaments.

BERNSTEIN—German Patent, 232373, Class 29a, issued March 15, 1910. Covers apparatus and process of denitrating nitrocellulose threads in the hank.

SOCIÉTÉ ANONYME POUR L'ÉTUDE INDUSTRIELLE DE LA SOIE
SERRET—French Patent, 369170. Covers the use of aluminum chloride solutions after partial denitration in the usual way.

GERMAIN—French Patent, 360396. Covers the use of ammonium magnesium and other phosphates or bi-carbonates for fireproofing nitrocellulose filaments.

PLAISETLY—British Patent, 9087—1900. Covers the use of aluminum salts for fireproofing nitrocellulose filaments.

WISLICKI—German Patent, 247095, Class 29b, issued Mar. 24, 1910. Covers the treatment of denitrated filaments with hot acidulated water in order to increase its strength.

CHARDONNET—British Patent, 10518—1915. Covers a system of treating nitro-Rayon with liquids.

The following patents relate to the art of solvent recovery:

- DEINS—German Patent, 165331, Class 29b, issued April 23, 1904. Covers a system of solvent recovery by causing the air laden with solvent vapors to pass through condensing coils.
- DERVIN—French Patent, 350298. Covers a system of solvent recovery based on aspirating the air laden with solvent vapors through an absorbing liquid from which the solvents are recovered by distillation.
- DERVIN—French Patent, 5757. Covers an improvement and addition to the above.
- JULES, JEAN & CIE AND GEORGES RAVERAT—British Patent, 13603—1905. Covers a system of solvent recovery by condensing same in acetic acid or phosphoric acid.
- DOUGE—French Patent, 356835. Covers a system of solvent recovery by absorption from the spooled filaments in a liquid in which they are immersed.
- DOUGE—British Patent, 1595—1907. Covers a system of solvent recovery based on baffling and placing resistance in the path of the aspirated vapors.
- AMENQUE—French Patent, 349843. Concerns a system of solvent recovery based on cooling the vapors.
- BONCHAND-PRACIEQ—Swiss Patent, 33684. Apparatus for solvent recovered based on absorption by liquids and subsequently distilling in vacuo.
- VITTENET—German Patent, 194825, Class 29a, issued June 19, 1906. Covers apparatus and arrangements of gathering pipes on the spinning frame to collect solvent vapors.
- BUCQUET—German Patent, 196699, Class 29b, issued Feb. 10, 1907. Covers use of fluid fat or fatty acid as absorbing mediums for solvent vapors.
- DIAMANTI AND LAMBERT—German Patent, 203916, Class 29b, issued March 3, 1907. Covers a system of hoods attached to the spinning frame to collect solvent vapors.
- SOCIÉTÉ L'AIR LIQUIDE—French Patent, 397791. Covers a condenser and cooler for the solvent vapors.
- CREPELLE-FONTAINE—French Patent, 396664. Covers a columnar still for solvent recovery.

- CREPELLE-FONTAINE—French Patent, 401182. Covers an absorbing tower using sulphuric acid as absorbing medium for solvent vapors.
- FABRIQUE DE SOIE ARTIFICIELLI DE TUBIZE—French Patent, 358987. Covers process steps from bobbin to final dryer.
- FABRIQUE DE SOIE ARTIFICIELLE DE TUBIZE—French Patent, 401262. Covers use of 62° Bé. sulphuric acid in towers for solvent recovery.
- FABRIQUE DE SOIE ARTIFICIELLE DE TUBIZE—French Patent, 412887. Covers a chamber with adjustable openings constructed around the spinnerettes for the purpose of collecting the solvent vapors.
- CHARDONNET—French Patent, 413359. Covers an improvement in the process of collecting solvent vapor-laden air from the spinning machines absorbing same in amyl alcohol and recovering same in a fractionating columnar still.
- CHARDONNET—French Patent, 376785. Covers an absorption and distillation process wherein an alcohol water mixture is used as absorbent for solvent vapors.
- CHARDONNET—French Patent, 377673. Covers an absorption and distillation process wherein the higher alcohols are used as absorbents for solvent vapors.
- ITALIAN CHARDONNET COMPANY—German Patent, 203649, Class 29b, issued Feb. 1, 1907. Covers process of absorbing solvents from the thread by passing same through a water solution of metallic salts.
- SOCIÉTÉ DE LA SOIE DE CHARDONNET—French Patent, 387054. Covers a system of solvent recovery by using compressors to condense the vapor-laden air.
- FOURNAUD—French Patent, 416064. Covers a construction of hoods to the left and right of the spinnerette for the purpose of collecting solvent vapors.
- SAUVERZAC—French Patent, 420086. Covers a system of solvent recovery based on the absorption of alcohol-ether vapors by a mixture of alcohol, water and metallic or organic chlorides.
- WOHL—German Patent, 241973, Class 29b, issued Nov. 13, 1910. Covers a system of solvent recovery based on the absorption of solvent vapors by cellulose-esters (such as nitrocellulose).
- CHANDELON—German Patent, 254913, Class 29b, issued Feb. 22, 1912. Covers the use of chorine, bromine, and nitro-deriva-

tives of the hydro-carbons having a boiling point over 100° C. as absorbents for alcohol-ether solvents.

DUCLAUX—French Patent, 16214. Further improvement in solvent vapor absorption by the use of formic acid.

DELPECH—French Patent, 441551. Covers the use of hygroscopic salts such as calcium magnesium and zinc chlorides as absorbers of alcohol-ether vapors.

BERGE—Belgian Patent, 250816. Covers the use of formic or acetic acid, also amyl alcohol, tetrachlorethane and nitrobenzol as absorbents of ether-alcohol vapors.

LOINTIER—Belgian Patent, 253805. Covers a construction of glass chambers surrounding the spinnerettes to collect and guide the alcohol-ether vapors.

DEINS AND BARBELENET—German Patent, 267509, Class 29a, issued Aug. 13, 1912. Covers a closed system of solvent recovery.

FRISCHER—British Patent, 7098—1915. Covers a system of solvent recovery based on using solutions of the solvents to be recovered and finally oil emulsions to entrap the last traces.

BARBET ET FILS ET CIE—British Patent, 101723. Covers a closed circuit system of solvent recovery using dilute sulphuric acid as absorbing medium.

BARBET ET FILS & CIE—British Patent, 101875. Covers an automatic indicating device to show the density of recovered or other solvents.

KNIFFEN—(Du Pont) U. S. Patent, 1236719. Covers a system of coils and tubes for the condensation of solvent vapors.

PERSCH—Swiss Patent, 78099. Covers a system of solvent recovery and separation which raises the vapors to the boiling point of one solvent and then cools them suddenly.

CRAIG-ROBERTSON-MASSON & DRUMMOND—British Patent, 129-024. Covers a system of solvent recovery consisting of a series of towers using alcohol, water and salt or acid as absorbents.

LEHNER—German Patent, 303396, Class 29b, issued Sept. 10, 1916. Covers a series of absorbing towers using sulphuric acid as absorbent so arranged as to advance the liquids from tower to tower automatically.

BREGEAT—U. S. Patent, 1315700. Covers construction of towers

and columnar stills, also the use of phenol as absorbing medium for solvent recovery.

CLAESSEN—German Patent, 300595, Class 29b, issued Feb. 19, 1916. Covers a system of purification for recovered solvents.

SOCIÉTÉ DE LA SOIE DE CHARDONNET—French Patent, 354398. Covers a system of cleaning the wadding and gauze used for filtering nitrocellulose.

HUNGARIAN CHARDONNET Co.—French Patent, 410652. Covers a system for recovering nitrogen and sulphur compounds formed during the denitration process.

SOCIÉTÉ DE SOIE ARTIFICIELLE DE TUBIZE—German Patent, 234672, Class 85c. Covers a system of treating the waste waters from the nitrocellulose process.

The following patents are of interest in connection with the cupra-ammonium process. They cover processes and equipment for the manufacture of Rayon from solutions of cellulose in copper oxide and ammonia:

DESPAISSIS—French Patent, 203741, issued May 9, 1890. Covers the process of converting cotton to Rayon filaments by dissolving the cotton in cupra-ammonium solutions, spinning as usual and coagulating and washing in suitable liquids.

PAULY—French Patent, 272718, issued in 1897. Covers the process of making Rayon filaments as above but with more specific details.

BRONNERT, FREMERY & URBAN—German Patent, 119230, Class 29b, issued July 10, 1900. Covers the use of ammoniacal copper carbonate as the solvent for cellulose.

VER. GLANZ STOFF, A.G.—German Patent, 169567, Class 29b, issued Jan. 17, 1905. Covers variations on the Pauly process and also the use of sulphuric acid as coagulant.

VER. GLANZ STOFF, A.G.—German Patent, 235134, Class 29b, issued Aug. 4, 1906. Covers a continuous process for spinning, washing, drying, spooling and twisting, and the apparatus therefor.

THIELE—German Patent, 154507, Class 29b, issued Jan. 20, 1901. Covers the stretch spinning modification of the usual copper ammonia processes.

- THIELE—German Patent, 157157, Class 29b, issued March 9, 1901. Covers special arrangements for the stretch spinning process wherein the thread is generated downward in a slowly acting coagulating bath and then drawn upward around a surface offering frictional resistance.
- THIELE—German Patent, 173628, Class 29b, issued April 14, 1902. Further modification of the above patents in that an alkaline coagulating bath of slow action is used.
- UEBEL—German patent, 225161, Class 29b, issued June 25, 1905. Modification of the Thiele patents in that, after stretching a concentrated alkaline bath is used.
- THIELE AND LINKMEYER—German Patent, 179772, Class 29b, issued Aug. 26, 1905. Covers the use of neutral or alkaline baths for stretching and subsequently passing through acid baths to remove the copper compounds.
- LINKMEYER—French Patent, 350888. Process patent covering use of dilute acid as precipitating and stretching bath, subsequently passing through a caustic soda bath, then through water, and finally through dilute acid to remove the copper salts.
- LINKMEYER—French Patent, 352528. Covers a spinning pot which besides its rotation has a lateral motion. This is claimed to gather the thread without sticking as is usual with the bobbins.
- SOCIÉTÉ DE LA SOIE ARTIFICIELLE LINKMEYER—French Patent, 356402. Covers an improvement in the cupra-ammonium process in that all uncombined ammonia is removed from the spinning solution by vacuum.
- SOCIÉTÉ DE LA SOIE ARTIFICIELLE LINKMEYER—German Patent, 175296, Class 29b, issued April 7, 1904. Covers the reduction of the ammonia content of the cupra-ammonium solution by kneading in vacuo.
- SOCIÉTÉ DE LA SOIE ARTIFICIELLE LINKMEYER—German Patent, 185139, Class 29b, issued Sept. 4, 1904. Modification of previous patents in that the thread is generated in air or a gas atomized with a liquid which precipitates cellulose.
- SOCIÉTÉ DE LA SOIE ARTIFICIELLE LINKMEYER—British Patent, 14655—1907. Covers an improvement in the stretch spinning machine.

- LINKMEYER & POLLAK—Swiss Patent, 40164. Modification of the stretch spinning process.
- FRIEDRICH—British Patent, 28256—1909. Modification of the stretch spinning process.
- MERTZ—Swiss Patent, 35642. Complete process patent from the pre-treatment of the cotton to the spooling and reeling of the finished product.
- KRACHT—French Patent, 355064. Modification of the stretch spinning process.
- BERNSTEIN—U. S. Patent, 798868. Formula patent for spinning solutions showing addition of silk boil off water.
- DREAPER—British Patent, 27222—1905. Modification of the cupra-ammonium process.
- BERENGUER—British Patent, 10545—1907. Improvements in making cellulose solution in cupra-ammonium, also in the composition of coagulating baths.
- FOLZER—German Patent, 209923, Class 29a, issued Aug. 25, 1908. Apparatus or trough acting as filament guide into which the various treating solutions are allowed to run.
- FOLZER AND DITZLER—German Patent, 210280, Class 29a, issued July 14, 1908. Spinning frame arrangement whereby the filament is passed through successive coagulating and treating baths of varying concentration by passing it around cylinders which rotate in the baths.
- BEMBERG—German Patent, 220051, Class 29a, issued May 16, 1907. Covers a spinning machine in which the forward movement of the filament is assisted by the movements imparted to the liquid of the coagulating bath.
- BEMBERG—German Patent, 303047, Class 29b, issued July 26, 1916. Improvement and modification of the preceding in that it covers a system of renewal for the moving or flowing coagulating bath.
- VEREINIGTE KUNSTSEIDE FABRIKEN, A.G.—German Patent, 230941, Class 29b, issued Jan. 18, 1908. Covers a high percentage cellulose solution using copper, oxychloride, copper hydroxide and copper carbonate to make up same.
- HANAUER KUNSTSEIDEFABRIK, G.m.b.H.—German Patent, 320711, Class 29b, issued July 25, 1907. Covers use of sodium resinate, glycerine and gelatine to increase the strength of

cupra-ammonium cellulose solution, whereby it is claimed lower pressures can be used.

HANAUER KUNSTSEIDEFABRIK, G.m.b.H.—German Patent, 222-873, Class 29b, issued May 31, 1908. Covers the manufacture of formed articles from cupra-ammonium cellulose solutions and finishing same in solutions of ammonium salts.

HANAUER KUNSTSEIDEFABRIK, G.m.b.H.—German Patent, 233-370, Class 29a, issued Oct. 15, 1908. Covers an addition to the spinning frame consisting of cylinders rotating in coagulating and fixing baths which cylinders are provided with a number of smaller cylinders which also rotate.

HANAUER KUNSTSEIDEFABRIK, G.m.b.H.—German Patent, 240-242, Class 29b, issued May 30, 1908. Covers a process for making cupra-ammonium cellulose solutions of low oxy-cellulose content by saturating same with copper tetramin-sulphate and heating.

BECHTEL—German Patent, 229711, Class 29b, issued Aug. 8, 1909. Covers a modified process for cupra-ammonium cellulose solutions by adding mechanically disintegrated cellulose to solutions prepared in the usual way.

GLANZFÄDEN, A.G.—German Patent, 241683, Class 29b, issued May 16, 1909. Covers the manufacture of formed articles made from cupra-ammonium cellulose solutions by treating them with chlorides of the alkaline earth metals.

DITZLER—German Patent, 244510, Class 29b, issued Jan. 25, 1911. Covers a process for making cupra-ammonium cellulose solutions and spinning same by excluding all air from them at all steps from solution to coagulation.

ECK—German Patent, 300254, Class 29a, issued April 22, 1913. Covers an addition to the spinning frame consisting of cylinders and guides so arranged that the filaments are led successively through various coagulating and fixing baths to drying plates, pulleys and finally the gathering bobbins.

The following patents cover the pre-treatment of cellulose necessary in order to prepare solutions of same with copper ammonia:

FREMERY AND URBAN—German Patent, 111313, Class 29b, issued

Mar. 17, 1899. Covers the pre-treatment of cellulose by using air oxidizing or reducing bleaching agent.

FREMERY, URBAN & BRONNERT—German Patent, 119099, Class 29b, issued May 13, 1899. Modifications of the processes cited above. Covers boil off in dilute alkali, subsequent bleaching, and then mercerization in strong alkalis, washing and dissolving in copper ammonia without drying.

FOLZER—French Patent, 345687. Covers pre-treatment of cellulose with a solution composed of water, sodium carbonate and caustic soda.

CRUMIERE—German Patent, 187263, Class 29b, issued Dec. 12, 1905. Covers the pre-treatment of cellulose with oxidizing agents such as ozone in the presence of alkalis.

SCHAEFER—U. S. Patent, 879416. Covers the addition of benzol to the caustic solutions used in kiering cellulose previous to making the copper ammonia solution.

MUELLER & WOLF—German Patent, 256351, Class 29b, issued Oct. 24, 1911. Covers preparation of copper ammonia cellulose solutions from hop-vines decorticated with soda and soft soap.

The following patents concern the preparation of copper ammonia solutions and copper hydroxy cellulose:

BRONNERT, FREMERY & URBAN—German Patent, 115989, Class 12, issued Jan. 11, 1900. Covers the preparation of copper ammonia solutions of high copper content by making use of the oxidizing effect of air or certain acids and keeping the temperature between 0° and 5° C.

PRU D'HOMME—French Patent, 344138. Covers the use of sodium and potassium hydroxides in making up the copper ammonia solution.

LECOEUR—German Patent, 185294, Class 29b, issued Feb. 9, 1906. Covers a process of purifying, by dialysis, ammonia to be used in the preparation of copper ammonia solutions.

LECOEUR—French Patent, 374277. Covers the purification of colloidal copper ammonia solutions by dialysis.

LE CRINOID—French Patent, 401741. Modification of the LecoEUR patent above.

- MERTZ—Swiss Patent, 34760. Covers a container with cylindrical bottom for making the copper ammonia solution.
- SOCIÉTÉ ANONYME LA SOIE NOUVELLE—French Patent, 369973. Covers an improved process for making metallic ammonia compounds by using an air injector.
- SCHAEFER—Swiss Patent, 45321. Process for making copper ammonia solutions at low temperatures (-8° to $+4^{\circ}$ C.).
- GLANZFÄDEN, A.G.—German Patent, 269787, Class 29b, issued Dec. 16, 1908. Process for making a stable concentrated solution of copper ammonia by using copper sulphate, then a sufficient quantity of alkali to precipitate all of the copper hydroxide, finally completing with alkali carbonate.
- BRITISH CELLULOSE, LTD.—German Patent, 250596, Class 29b, issued Jan. 14, 1910. Process for preparing a stable and concentrated solution of copper ammonia by using perborates or per-sulphates of sodium or ammonium and some organic compounds such as acetone chlorhydrin, acetic acid, citric acid, tartaric acid, etc.
- BETTENHAUSEN, MARGUARD & SCHULTZ—French Patent, 399911. Process for preparing a stable solution of copper ammonia by the use of organic compounds such as alcohol, glycerine, grape sugar, lactose, starch, etc.
- FOLZER—German Patent, 229677, Class 12n, issued April 4, 1908. Covers apparatus and process for making copper ammonia solution continuously.
- BERNSTEIN—U. S. Patent, 965273. Process for preparing copper ammonia solutions by the addition of various sugars.
- BERNSTEIN—German Patent, 248303, Class 29b, issued July 15, 1910. Process for preparing copper ammonia solutions by adding sugars, gum arabic and glycerine.
- BRONNERT—German Patent, 109996, Class 29, issued May 2, 1899. Process for copper hydroxy cellulose soluble in ammonia.
- BEMBERG—German Patent, 162866, Class 29b, issued Sept. 29, 1900. Process for preparing cellulose compounds soluble in ammonia by first treating the cellulose with metallic copper.
- BEMBERG—German Patent, 174508, Class 29b, issued Feb. 23, 1905. Modification of preceding process in that cuprous hydroxide is used instead of metallic copper.

- MAHLER—Austrian Patent, 18454, Class 29b. Improvement in the process of making copper ammonia cellulose solutions.
- SPENCE & SONS—Process for making a copper ammonia solution for use in dissolving cellulose.
- WASSERMAN—German Patent, 274658, Class 29b, issued Jan. 10, 1913. Process for making an improved copper ammonia solution for dissolving cellulose.
- SOCIÉTÉ GÉNÉRALE POUR FABRICATION DES MATIÈRES PLASTIQUES—German Patent, 113208, Class 29b, issued July 15, 1899. A process for preparing copper ammonia cellulose solutions by keeping the ammonia content saturated.
- LANGHANS—German Patent, 140347, Class 29b, issued June 8, 1899. Covers a process for preparing solutions of cellulose in copper and nickel ammonia solutions.
- LINKMEYER—German Patent, 183153, Class 29b, issued June 3, 1904. Process for preparing a solution of cellulose by using, first, a less concentrated copper ammonia bath containing caustic soda and then using a similar but concentrated bath.
- LINKMEYER—German Patent, 187313, Class 29b, issued June 9, 1904. Covers a modification of the above process using injected air to remove ammonia.
- LINKMEYER—U. S. Patent, 962770. Covers the addition of the higher alcohols (for example dulcitol and mannitol) to copper ammonia solutions used in dissolving cellulose.
- FRIEDRICH—French Patents, 357171, 364066, and 372002. The above cover processes for preparing solutions of cellulose. The first by using alkylamine, the second and third by using metallic hydroxyde ammonia compounds.
- GLANZFÄDEN, A.G.—German Patent, 228872, Class 29b, issued Feb. 20, 1908. Covers the addition of carbohydrates to the usual copper ammonia solutions.
- GLANZFÄDEN, A.G.—German Patent, 230141, Class 29b, issued March 31, 1908. Covers the use of other carbohydrates of plant origin (other than cellulose) for making stable spinning solutions.
- GLANZFÄDEN, A.G.—German Patent, 241921, Class 29b, issued July 7, 1909. Modification of the above patent.
- GLANZFÄDEN, A.G.—German Patent, 306107, Class 29b, issued Oct. 13, 1917. Covers the use of cane and grape sugar in

the process of making spinning solutions of cupra-ammonium and cellulose.

GUADAGNI—German Patent, 216669, Class 29b, issued Jan. 18, 1908.

GUADAGNI—British Patent, 25986—1910. Process and apparatus for preparing cupra-ammonium solutions of cellulose and improvements thereon.

PAWLIKOWSKI—German Patent, 222624, Class 29b, issued May 22, 1908. Process for preparing solutions of cellulose in suspensions of solutions of copper oxychloride in the presence or absence of other copper compounds.

BOUCQUEY—French Patent, 376065. Process for dissolving cellulose by means of any desired copper salt.

HÖMBERG—German Patent, 237717, Class 29b, issued Aug. 5, 1909. Process for making filaments, films and other articles from copper ammonia cellulose solutions to which aldehyde or aldehyde compounds are added.

RHEINISCHE KUNSTSEIDE FABRIK, A.G.—German Patent, 231652, Class 29b, issued May 5, 1909. Improvement in the process of making cupra-ammonium cellulose solutions.

HANAUER KUNSTSEIDE FABRIK, G.m.b.H.—German Patent, 231693, Class 29b, issued May 3, 1906; German Patent, 260650, Class 29b, issued May 19, 1908; German Patent, 235219, Class 29b, issued Jan. 21, 1909. These cover process details for making cupra-ammonium cellulose solutions.

ECK—German Patent, 240082, Class 29b, issued May 22, 1909. Modification of process for making the cupra-ammonium cellulose solution by treating cellulose first with washed copper hydroxyde reducing in the cold and adding ammonia last.

COMPAGNIE DES APPLICATIONS DE LA CELLULOSE—French Patent, 429841. Process details for very concentrated cellulose solutions.

TRAUBE—German Patent, 245575, Class 29b, issued Jan. 10, 1911. Process details for making stable cupra-ammonium cellulose solutions by treating the usual solvents with aliphatic diamines.

DE HAEN—German Patent, 251244, Class 29b, issued June 24, 1911. Process for making spinning solutions from plant substance, especially straw.

- DE HAEN—French Patent, 436968. Process for cupra-ammonium cellulose solution.
- SOCIÉTÉ DE LA SOIE ARTIFICIELLE DU NORD—French Patent, 437815. Improvement in the process of making a stable solution of cellulose with copper salts.
- SPENCE & SONS—German Patent, 264951, Class 29b, issued Oct. 29, 1912. Process for making a cellulose solution by precipitating metallic copper in the cellulose mass and subsequently using the usual cupra-ammonium reagents.
- BORZYKOWSKI—French Patent, 450193. Process for making a cellulose solution with cupra-ammonium.
- MUELLER—French Patent, 451406. Process details for making a viscous cellulose solution.

The following patents concern coagulants for copper ammonia cellulose solutions, especially those of an acid nature:

- BRONNERT, FREMERY & URBAN—German Patent, 125310, Class 29b, issued Oct. 19, 1900. Covers a coagulating bath using a 30 per cent to 65 per cent solution of sulphuric acid.
- FOLZER & WEISS—Swiss Patent, 37584. Device and arrangement for coagulating filaments from cellulose.
- SOCIÉTÉ LA SOIE NOUVELLE—French Patent, 365037. Covers a coagulating bath of glycerine and sulphuric acid.
- BOUCQUEY—French Patent, 368706. A coagulating bath of dilute acid to which sugar is added.
- LECOEUR—French Patent, 381939. A coagulating bath consisting of solutions of the alkali metal bisulphates.
- FRIEDRICH—French Patent, 403427. A coagulating bath consisting of the chlorides of the alkaline earth metals to which alcohol, carbo-hydrates and various gums can be added.
- HANAUER KUNSTSEIDE FABRIK, G.m.b.H.—German Patent, 221-041, Class 29b, Sept. 6, 1908. Process for the production of filaments from copper ammonia cellulose solutions by using as coagulating bath various sulphites which are continuously regenerated by adding gaseous SO_2 .

The following patents concern coagulating baths of alkaline nature:

- LINKMEYER—French Patent, 347960. Covers a coagulating bath of composition similar to a mercerizing bath.
- LINKMEYER—French Patent, 361061. Process covering a coagulating bath of salts and caustic, the salts being principally carbonates, chromates, oxalates, phosphates, borates of sodium or potassium.
- LINKMEYER—U. S. Patent, 1022097. Complete process for making fine artificial filaments with especial reference to a coagulating bath consisting of salt and caustic soda.
- FARBWERKE, LUCIUS & BOÜNING—German Patent, 186387, Class 29b, issued Sept. 14, 1904. Process for making filaments from a copper ammonia cellulose solution by coagulating same in concentrated caustic soda subsequently washing with acids and water.
- VEREINIGTE GLANZSTOFF FABRIKEN, A.G.—German Patent, 190217, Class 29b. Modification of preceding patent in that a dilute alkaline coagulating bath is used.
- VEREINIGTE GLANZSTOFF FABRIKEN, A.G.—German Patent, 208472, Class 29b, issued April 23, 1907. Process for making filaments and films from copper ammonia cellulose solutions using a coagulating bath of concentrated caustic soda to which glucose, saccharose, lactose or glycerin are added.
- VEREINIGTE GLANZSTOFF FABRIKEN, A.G.—German Patent, 218490, Class 29b, issued April 23, 1907. Modification of the preceding patent in that a subsequent bath of a solution of magnesium or ammonium sulphate is used previous to the final drying.
- VEREINIGTE GLANZSTOFF FABRIKEN, A.G.—German Patent, 229863, issued Oct. 1, 1907. Further modification of patent 208472, in that a temperature range of from 45° to 75° C. is specified for the coagulating bath.
- VEREINIGTE GLANZSTOFF FABRIKEN, A.G.—Austrian Patent, 35272. Covers the temperature control of an alkaline coagulating bath at from 45° to 65° C.
- VEREINIGTE GLANZSTOFF FABRIKEN, A.G.—German Patent, 259816, Class 29b, issued Oct. 21, 1910. Process for the continuous production of filaments from cupra-ammonium cellulose solutions.
- VEREINIGTE GLANZSTOFF FABRIKEN, A.G.—German Patent, 268261, Class 29b, issued Sept. 3, 1912. Process for making

- filaments or forms of copper cellulose solutions by coagulating in a dilute caustic soda solution ($2\frac{1}{2}\%$) and subsequently treating in a bath of the salts of the oxygen acids.
- MUELLER—French Patent, 373429. Process for making lustrous cellulose products.
- SOCIÉTÉ LA SOIE ARTIFICIELLE—French Patent, 379000. Covers an alkaline coagulating bath at 40° to 60° C.
- CUNTZ—French Patent, 383413. Process based on a coagulating bath containing salt, caustic soda, soda ash, caustic lime and calcium chloride.
- LECOEUR—French Patent, 392869. Process for making filaments of fine denier.
- DREAPER—British Patent, 20316—1908. Improvements in the process of making filaments from solutions of cellulose by adding various substances such as glucose, glycerine, etc., to the coagulating bath as well as to the spinning solution.
- SOCIÉTÉ LE "CRINOÏD"—British Patent, 22413—1909. Improvements in alkaline coagulating baths.
- FRIEDRICH—German Patent, 206883, Class 29b, issued Aug. 27, 1907. Covers a coagulating bath containing the alkali chlorides as well as the caustic alkalis.
- HANAUER KUNSTSEIDE FABRIK, G.m.b.H.—German Patent, 187-696, Class 29b, issued May 3, 1906. Process for making articles from cupra-ammonium cellulose solutions by treating the filament or form in a warm solution of caustic soda and subsequently drying in air, then proceeding with the usual baths.
- HANAUER KUNSTSEIDE FABRIK, G.m.b.H.—German Patent, 255-549, Class 29b, issued Oct. 14, 1911. Covers the preheating of the cupra-ammonium spinning solution before coagulating it in either a warm or cold alkaline bath.
- HÖMBERG—German Patent, 235366, Class 29b, issued July 23, 1910. Covers a coagulating bath for cupra-ammonium cellulose filaments consisting of the usual alkalis to which are added certain colloids such as albuminous substances (white of egg, gelatine and the like) which have been acted upon by pepsin.
- ECK—German Patent, 236297, Class 29b. Covers a coagulating bath of the usual alkalis to which methyl and ethyl alcohol and formaldehyde are added.

- COMPAGNIE FRANÇAISE DES APPLICATIONS DE LA CELLULOSE—
French Patent, 422565. Covers a coagulating bath consisting
of calcium saccharate and caustic soda.
- COMPAGNIE FRANÇAISE DES APPLICATIONS DE LA CELLULOSE—
German Patent, 252180, Class 29b, issued May 25, 1911.
Covers an alkaline coagulating bath to which soluble arsenates
are added.
- PAWLIKOWSKI—German Patent, 248172, Class 29b, issued Oct.
2, 1910. Process for coagulating forms and filaments from
copper oxy-ammonia cellulose solutions by adding sodium
or potassium aluminate to the alkaline bath.
- LEGRAND—German Patent 250357, Class 29b, issued Oct. 15,
1911. Covers an alkaline coagulating bath to which diastase
is added.
- DE HAIN—French Patents, 440907 and 15861. Cover complex
formulas for coagulating baths consisting principally of soda
saltpeter, sodium nitrite, caustic soda and sodium arsenite.
- GLANZFÄDEN, A.G.—German Patent, 286297, Class 29b, issued
Aug. 17, 1913. Process for making forms and filaments
from cupra-ammonium cellulose solutions using a coagu-
lating bath containing copper carbonate together with the
usual alkalis.

The following patents cover such processes for treating
cellulose filaments as come after coagulation, namely, copper
removal, washing and drying:

- CRUMIERE—German Patent, 228504, Class 29b, issued June 9,
1907. Covers a process of copper removal by means of an
acid bath through which an electric current is passed.
- FREMERY & URBAN—German Patents, 111409, Class 29, and 111-
790, Class 29, issued in 1899. Washing device whereby
acidulated water and pure water are sprayed on the spools
containing the films or filaments to be washed.
- FOLZER—German Patent, 165577, Class 29a, issued April 9, 1905.
Special washing machine for bobbins.
- BERNSTEIN—U. S. Patent, 960791. Covers washing with water
at 25° to 30° C.
- FREMERY & URBAN—German Patent, 121429, Class 29b, issued

- Mar. 10, 1899. Covers washing and partial drying on the bobbin or reel.
- FREMERY & URBAN—German Patent, 121430, Class 29b, issued Aug. 13, 1899. Covers an improvement on the above.
- LINKMEYER AND POLLAK—French Patent, 350889. Process for improving the lustre of cellulose filaments.
- LINKMEYER—French Patents 357837 and 361061. Process for improving cellulose filaments.
- THIELE—German Patent, 134312, Class 29b, issued Jan. 27, 1901. Process for increasing the strength of cellulose filaments, by treating them with alcohol and heating them to higher temperatures.
- PAWLIKOWSKI—French Patent, 417851. Special spool or bobbin for giving wound filaments a stretch.
- PAWLIKOWSKI—German Patent, 237200, Class 29a, issued Dec. 12, 1909. Device and process for twisting and spooling cellulose threads.
- LINKMEYER—French Patent, 352530. Improvements on devices for twisting and reeling.
- SPENCE & SONS—German Patent, 265204, Class 29b, issued Oct. 12, 1912. Process for making metal-like threads from copper ammonia cellulose solutions.

The following patents apply to the recovery of various chemicals used in the manufacture of cupra-ammonium Rayon:

- LINKMEYER—German Patent, 184150, Class 29b, issued April 8, 1905. For the recovery of copper by absorbing same from the spent liquors by means of cellulose.
- CUNTZ—French Patent, 383412. For the recovery of copper by means of grain chaff, seeds and the like and the ammonia by heating and condensation.
- VEREINIGTE GLANZSTOFF-FABRIKEN, A. G.—German Patent, 235476, Class 29b, issued June 19, 1910. Process for the recovery of copper and ammonia.
- VEREINIGTE GLANZSTOFF-FABRIKEN, A. G.—German Patent, 239214, Class 29b, issued June 19, 1910. Process for the recovery of copper and ammonia.

The following patents apply to the Viscose process and the first group are concerned especially with the preparation of the Viscose solution:

- CROSS, BEVAN & BEADLE—British Patent, 8700—1892. Process details for making viscoïd by treating cellulose with caustic soda and carbon bisulphide.
- CROSS—British Patent, 4713—1896. Covers an improvement on the above process.
- VISCOSE SYNDICATE—German Patent, 133144, Class 8i, issued March 31, 1901. Process for purifying Viscose by using weak organic acids.
- SOCIÉTÉ FRANÇAISE DE LA VISCOSE—German Patent, 163661, Class 29b, issued March 2, 1904. Process for removing air entrained in the Viscose solution by using reduced pressures.
- SOCIÉTÉ FRANÇAISE DE LA VISCOSE—French Patent, 339564. Digester for treatment of Viscose.
- SOCIÉTÉ FRANÇAISE DE LA VISCOSE—French Patent, 334636. Process for preparing a purified Viscose solution.
- SOCIÉTÉ FRANÇAISE DE LA VISCOSE—German Patent, 223736, Class 29b, issued Feb. 1, 1907. Process for enriching and ripening Viscose by using reduced pressures and temperatures.
- CONTINENTALE VISCOSE COMPAGNIE—German Patent, 209161, Class 29b, issued Oct. 20, 1903.—Process for purifying Viscose by treatment with gaseous CO_2 .
- VEREINIGTE KUNSTSEIDE FABRIK, A.G.—German Patent, 183623, Class 29b, issued June 21, 1902. Process for ripening Viscose by heating to temperatures over 40°C .
- VEREINIGTE KUNSTSEIDE FABRIK, A.G.—German Patent, 200023, Class 29b, issued April 23, 1907. Process for coagulating Viscose threads or films in acid baths with the help of aluminum and chromium salts.
- BEMBERG—German Patent, 197086, Class 29b, issued March 29, 1907. Process for purifying Viscose solutions.
- LE CLAIRE—French Patent, 402804; British Patent, 20593—1909. Covers apparatus and process for making Viscose and similar compounds.
- LYNCKE—German Patent, 237261, Class 120, issued Sept, 22,

1907. Process for making powdered or crumbled cellulose xanthate.

PELLERIN—French Patent, 417568. Process for making a solution of cellulose xanthate.

LILLIENFELD—German Patent, 228836, Class 120, issued Oct. 28, 1906. Process for making cellulose xanthate solutions, especially by heating.

LILLIENFELD—German Patent, 323891, Class 29b, issued June 12, 1914. Process for making cellulose xanthate solutions.

BECKER—German Patent, 234861, Class 29b, issued Aug. 16, 1910. Process for purifying Viscose solutions by dialysis.

BURETTE—French Patent, 430221. Improvements in the process of making cellulose xanthate.

BERNSTEIN—French Patent, 462147. Process for the preparation of a Viscose solution from wood cellulose.

COURTAULDS, LTD.-GLOVER & WILSON—Swiss Patents 70744 and 71681. Process details for making an oxidation product from alkali cellulose.

SOCIÉTÉ ANONYME DE ST. CHAMOND—Swiss Patent, 71312. Process details for making a Viscose solution suitable for the manufacture of Rayon.

LINKMEYER AND HOGERMANN—German Patent, 312392, Class 29b, issued Nov. 17, 1917. Process for preparing an improved, stable Viscose solution by adding amide or imide groups thereto.

The following patents concern the art of purifying alkali-cellulose and the recovery of the caustic wastes:

GIRARD—French Patent, 443897. Process for purifying wood pulp to be used for Viscose solutions by treating same with organic solvents such as the alcohols acetone, carbon tetrachloride to which formaldehyde is added.

LA SOIE ARTIFICIELLE—German Patent, 270618, Class 120, issued April 2, 1912. Soaking press for making alkali cellulose.

LA SOIE ARTIFICIELLE—German Patent, 252179, Class 29b, issued Jan. 19, 1912. Process for regenerating alkali waste liquors containing dissolved cellulose by treatment with salts of the heavy metals, especially copper.

KUTTNER—German Patent, 287092, Class 29b, issued July 1, 1914.
Process for purifying alkali waste liquors by dialysis.

The following patents concern the preparation of Rayon filaments from Viscose:

STEARN—German Patent, 108511, Class 29, issued Oct. 18, 1908.
Process details especially as regards coagulation in ammonium chloride baths.

STEARN—British Patent, 2529—1902. Coagulating bath at 10 to 20° C., containing chromium and aluminum sulphate.

STEARN—British Patent, 7023—1903. Process for making filaments from cellulose.

VEREINIGTE KUNSTSEIDE FABRIKEN, A.G.—British Patent, 17503—1902. Process for making colorless cellulose filaments.

VEREINIGTE KUNSTSEIDE FABRIKEN, A.G.—British Patent 330—1913. Coagulating bath consisting of a solution of formic acid.

VEREINIGTE KUNSTSEIDE FABRIKEN, A.G.—German Patent, 267-731, Class 29b, issued June 27, 1911. Process for making high lustre filaments by using as coagulating bath a solution containing salt and sulphuric acid.

HENCKEL VON DONNERSMARCK—German Patent, 152743, Class 29b, issued July 2, 1903. Process for making Viscose filaments by treating same with solutions of metallic salts subsequent to coagulation in ammonia baths.

HENCKEL VON DONNERSMARCK—German Patent, 153817, Class 29b, issued Jan. 28, 1904. Modification of above in that the metallic salts are added to the ammonia bath directly.

ERNST—U. S. Patents, 792888, 798027, 863793, and 896715.
Cover the preparation of filaments from Viscose and similar substances.

PISSAREX—French Patent, 357056. For coagulating Viscose films and filaments by using salts of organic bases.

SOCIÉTÉ FRANÇAISE DE LA VISCOSE—French Patent, 361319.
Covers the use of mixtures sodium and potassium silicates or aluminates in coagulating baths.

MUELLER—German Patent, 187947, Class 29b, issued May 2, 1905. Process for making filaments, films, bands or plates

by forcing Viscose solutions through suitable apertures into coagulating baths containing sulphuric acid and a salt.

VEREINIGTE GLANZSTOFF FABRIKEN, A.G.—German Patent, 240846, Class 29b, issued Sept. 26, 1908. Process (with formula examples) for making Viscose filaments and films by coagulating in a bath containing mineral acid, with salts especially sulphates of ammonia and magnesium and organic substances such as glycol, higher alcohols and fatty acids.

VEREINIGTE GLANZSTOFF FABRIKEN, A.G.—German Patent, 260479, Class 29b, issued Sept. 16, 1911. Similar to above except that a zinc salt is added to the coagulating bath.

VEREINIGTE GLANZSTOFF FABRIKEN, A.G.—German Patent, 283286, Class 29b, issued April 16, 1913. Similar to above except that citric and tartaric acids are used instead of glycol and some of the salt is dissolved in the Viscose solution.

VEREINIGTE GLANZSTOFF FABRIKEN, A.G.—German Patent, 282789, Class 29b, Nov. 27, 1913. Covers a process for making filaments and films of unripened Viscose by using a weak acid coagulating bath and passing the filament through the bath quickly.

VEREINIGTE GLANZSTOFF FABRIKEN, A.G.—German Patent, 287955, Class 29b, issued Feb. 15, 1912; Swiss Patent, 70123; Swiss Patent, 70124. Various process details for making filaments and films from Viscose solutions.

SOCIÉTÉ PINEL FRÈRES—French Patent, 400577. Coagulating bath for Viscose.

WAITE—U. S. Patents, 816404 and 849823. Coagulating bath for Viscose.

CHAVASSIEU—Swiss Patent, 47266. Process for making articles from cellulose and albumins.

BRANDENBERGER—British Patent, 24045—1911, also French Patent, 457633. Processes for coagulating acid regenerating Viscose.

BOISSON—French Patent, 436590. Process for coagulating cellulose xanthate solutions.

CHEMISCHE FABRIK VON HEYDEN, A.G.—French Patents, 426-436, 449536, 449536, and 451156. Processes for making Viscose filaments, films and ribbons.

KUTTNER—French Patents 451276 and 253569. Processes for making Rayon fibres from Viscose.

- LEDUC-JACQUEMIN, ET AL.—French Patent, 454061. Process for coagulating Viscose.
- STEIMMIG—German Patent, 290832, Class 29b, Feb. 16, 1913. Process for forming various cellulose objects especially films and filaments from Viscose by coagulating same with neutral salts of the alkali or the alkaline earths to which ammonia salts are added.
- BORZYKOWSKI—British Patent, 12090—1913, also French Patent, 489881. Process for making articles from Viscose.
- LACROIX—Belgian Patent, 256901. A coagulating bath for Viscose containing acetic acid and sodium acetate.
- PETIT—French Patent, 461900. Process for preparing derivatives of cellulose xanthate.
- VERHAVE—Swiss Patent, 71447. Spinning bath for Viscose.
- SILKIN KUNSTSEIDEN INDUSTRIE, G.m.b.H.—Austrian Patent, 67113. Process for making artificial fibres and the like from solutions of cellulose xanthate.
- LANGE AND WALTHER—German Patent, 307811, Class 29b, issued June 20, 1913. Process for coagulating Viscose by using a bath containing aldehyde bisulphite.
- SOCIÉTÉ ANONYME DES CELLULOSES PLANCHON—French Patent, 474727. Coagulating bath for Viscose.
- SOCIÉTÉ ANONYME FRANÇAISE KODAK—French Patent, 477735. Improvement in the methods of handling Viscose.
- BIROLI—U. S. Patent, 1226178. Process for making filaments from Viscose.

The following patents are of interest as relating to especial mechanical devices applicable to the Viscose process:

- SOCIÉTÉ FRANÇAISE DE LA VISCOSE—German Patent, 164321, Class 29a, issued Aug. 6, 1904. Covers a rotating spinnerette.
- SOCIÉTÉ FRANÇAISE DE LA VISCOSE—German Patent, 163467, Class 29a, issued Aug. 9, 1904. Covers a special valve for regulating the flow of Viscose to the spinnerette.
- SOCIÉTÉ FRANÇAISE DE LA VISCOSE—French Patent, 361877. Covers a rotating spinnerette.
- SOCIÉTÉ FRANÇAISE DE LA VISCOSE—German Patent, 160244,

Class 29a, issued Aug. 12, 1904. Device for throwing a spinning pot out of gear.

SOCIÉTÉ FRANÇAISE DE LA VISCOSE—French Patent, 345343. Replaceable insert for spinning Viscose.

SOCIÉTÉ FRANÇAISE DE LA VISCOSE—German Patent, 192406, Class 29a, July 16, 1906. Device for spinning and carrying Viscose filament progressively through various baths.

ERNST—U. S. Patents, 808148 and 808149. Apparatus for making filaments of Viscose and similar substances.

WADDELL & PETTIT—U. S. Patent, 846879. A device for winding Viscose filaments as produced.

WADDELL & PETTIT—U. S. Patents 849822 and 849870. Cover devices for forming filaments.

WADDELL & PETTIT—U. S. Patent, 823009. Spinnerette heads.

ERNST—U. S. Patent, 858648. Spinnerette heads.

COURTAULDS-TETLEY & CLAYTON—British Patent, 19158—1908. An improved device for manufacturing artificial fibres.

SAMUEL COURTAULDS & CO., LTD.—British Patent, 19157—1908. An improved carrier spindle for spinnerettes.

TETLEY & CLAYTON—British Patent, 17876—1907. An improved arrangement of pump for regulating the flow of Viscose liquids.

SAMUEL COURTAULDS & CO.—British Patent, 25097—1908. An improved spinning pot receptacle.

HENKEL VON DONNERSMARCK—German Patent, 189139, Class 29a, issued July 5, 1903. Geared pump with pressure equalizing bulb.

SOCIÉTÉ GÉNÉRALE DE SOIE ARTIFICIELLE PAR LE PROCÉDE VISCOSE—Austrian Patent, 25175. Device for filtering and feeding Viscose.

LE CLAIRE—French Patent, 399727. Regulating device to keep flow of spinning solution constant.

LE CLAIRE—French Patent, 406724. Spinning device fixed or rotating with an arrangement for cleaning the spinnerettes.

LE CLAIRE—French Patent, 414520. Water turbine to jointly drive the feed pump and the spinnerette.

LE CLAIRE—French Patent, 425953. An improved spinning pot.

LE CLAIRE—French Patent, 431681. Spinning device for making twisted artificial filaments.

- LEQUEUX—French Patent, 415619. Device for uncoupling spinning pumps.
- CATALA—French Patent, 430876. Machine for spinning viscous liquids, especially Viscose.
- DEINS—Belgian Patent, 259219. Machine for the simultaneous spinning, washing and drying of Viscose filaments.

The following patents relate to the various arts of treating Viscose Rayon such as washing, bleaching, spooling, twisting and to the recovery of chemicals:

- ERNST—U. S. Patent, 805456. Bleaching process.
- ERNST—U. S. Patent, 876533. Twisting machine.
- WADDELL—U. S. Patent, 867623. Twisting machine.
- WAITE—U. S. Patent, 759332. Process for treating Viscose filaments with steam and sulphur dioxide.
- SOCIÉTÉ FRANÇAISE DE LA VISCOSE—German Patent, 168171, Class 29a, issued Aug. 10, 1904. Winding machine.
- SOCIÉTÉ FRANÇAISE DE LA VISCOSE—French Patent, 340812. Machine for fixing Viscose filaments under tension with the aid of dilute acid solutions.
- HENCKEL VON DONNERSMÄRCK—German Patent, 212954, Class 29a, issued June 26, 1907. An arrangement for spinning Viscose filaments.
- COURTAULDS, LTD.—German Patent, 279310, Class 12i, issued July 27, 1913. Process for freeing sulphurized solutions from contained sulphur by forming polysulphides.

The following patents relate to the art of making Rayon fibres from fatty acid compounds of cellulose, particularly cellulose acetate:

- MORK, LITTLE & WALKER—U. S. Patent, 712200. Process for making artificial fibres from cellulose esters, particularly tetra-acetyl cellulose.
- MORK—British Patent, 20672—1910; U. S. Patents, 1074092 and 1107222. Processes for making cellulose acetate and also filaments, films and forms therefrom.
- LEDERER—French Patent, 330714; German Patents, 188542, Class

- 29b, 210778, Class 29b, and 240751, Class 29b. Cover methods of acetylizing cellulose and processes for making filaments, films and formed articles from cellulose acetate.
- GUIDO DONNERSMARCK—German Patent, 237599, Class 29b, issued Oct. 16, 1907. Process for making artificial fibres from cellulose acetate dissolved in formic acid.
- FARBEN FABRIKEN VORM, FRIEDRICH BAYER CO.—British Patent, 28733—1904. A new artificial fibre from triacetyl cellulose.
- FARBEN FABRIKEN VORM, FRIEDRICH BAYER CO.—French Patent, 418309; also British Patent, 13464—1910. Processes for making cellulose acetate and articles therefrom.
- KNOLL & Co.—German Patent, 196730, Class 29b, April 11, 1906; German Patent, 201910, Class 29b, Feb. 19, 1907; and German Patent, 234028, Class 29b Feb. 21, 1908. Process and improvements thereon for making a stable cellulose acetate derivate, also solutions thereof and articles therefrom.
- KNOLL & Co.—German Patent, 225704, Class 29b, issued Nov. 13, 1911; and German Patent, 274260, Class 29b, issued July 18, 1912. Processes for making non-brittle filaments and forms from cellulose acetate solutions.
- KNOLL & Co.—German Patent, 276013, Class 29b, issued Nov. 14, 1912. Process for making objects from cellulose acetate having a permanent white color.
- KNOLL & Co.—Austrian Patent, 64085. Process for rendering cellulose acetate insoluble in acetic acid chloroform and other solvents.
- KNOLL & Co.—German Patent, 286173, Class 29b, issued Oct. 10, 1912. Process for making cellulose acetate fibres.
- VEREINIGTE GLANZSTOFF FABRIKEN, A.G.—British Patent, 15700—1910. Process for making cellulose formate from Rayon wastes of all classes and also for making filaments and films therefrom.
- DREYFUSS & SCHNEEBERGER—French Patent, 413787; and British Patent, 20979—1911. Process for making cellulose acetate fibres.
- WOHL—French Patent, 425900. Process for making solutions of cellulose esters.
- CHEMISCHE FABRIK HEYDEN, A.G.—French Patent, 426436. New process for making Rayon from cellulose esters of the fatty acids.

DAMMAN—German Patent, 287073, Class 29b, issued June 12, 1913. Process for making filaments and films from cellulose acetate solutions.

VIEWEG—French Patent, 474163. Process for making filaments for Rayon from cellulose acetate solutions.

LILLIENFELD—British Patent, 6387—1913. An improved cellulose acetate process.

BEATTY—U. S. Patent, 1156969. Covers process for making filaments from a mixture of cellulose acetate and dioxydimethyl-diphenyl methane.

The following patents relate to arts, processes, machinery and devices which are possible of application in any of the various processes of Rayon production, and may be grouped into several classes as follows:

- (1) Pretreatment of cellulose.
- (2) Solvents for cellulose, methods of effecting solution and purifying same.
- (3) Filtering, air removal and feeding devices.
- (4) Spinnerettes and the manufacturing and cleaning thereof.
- (5) Spinning processes and machinery.
- (6) Winding machines, spools, bobbins and reels, twisting and reeling.
- (7) Washing and drying.
- (8) Special treatments for waterproofing, parchmentizing, lustre removal, opaquing, etc.

The following patents relate to the art of cellulose pretreatment:

GLURN—German Patent, 217316, Class 29b, Oct. 16, 1908. Process for pretreating cellulose by heating same in glycérine or oil at temperatures over 100° C.

OPFERMAN, ET AL.—German Patent, 219085, Class 29b, issued April 16, 1909. Process for purifying commercial bisulphite pulp by boiling same under pressure with sodium carbonate containing a small amount of sodium sulphide.

VEREIN FÜR CHEM. INDUSTRIE—German Patent, 290131, Class 29b, issued May 31, 1913. Method for pretreating cellulose with dilute acids so that neither oxy nor hydro-cellulose is formed.

The following patents relate to special solvents, etc.:

LANGHANS—German Patent, 72572, Class 21, issued June 17, 1891. Process for converting cellulose into a formable homogeneous mass by the use of sulphuric acid.

LANGHANS—German Patent, 82857, Class 29, issued April 16, 1893. Process for making a spinnable solution from cellulose by means of sulphuric and phosphoric acids.

HOFFMANN—German Patent, 227198, Class 29b, issued Aug. 27, 1909. Process for making a spinnable cellulose solution by using acetic acid and phosphoric acid.

VEREINIGTE GLANZSTOFF FABRIKEN, A.G.—Austrian Patent, 54819. Process for making spinnable solutions from cellulose by using formic and phosphoric acids.

BERL—German Patent, 259248, Class 29b, June 11, 1912. Process for making spinnable solutions from sulphuric acid solutions of cellulose.

WELLSTATTER—German Patent, 273800, Class 29b, issued May 25, 1913. Process for making solutions of cellulose in hydrochloric acid which can be coagulated in water, alcohol and salt solutions.

WEIMARN—German Patent, 275882, Class 29b, issued April 27, 1912. Process for converting cellulose of all kinds to plastic masses.

ZELLSTOFF FABRIK WALDHOF AND HOTTENROTH—German Patent, 306818, Class 29b, issued Jan. 3, 1917. Process for making solutions from any substance containing cellulose.

OSTENBERG—U. S. Patents, 1218954, 1242030, and 1315393. Processes for dissolving cellulose.

ELECTRO OSMOSE—German Patent, 296053, Class 78c, issued June 17, 1914. Process for purifying cellulose.

The following patents cover filtering devices, air removal and feeding devices:

- RHEINISCHE KUNSTSEIDE FABRIK, A.G.—German Patent, 246-780, Class 12d, issued Feb. 14, 1911. A filter apparatus for spinning solutions.
- LA SOIE DE BASECLES—German Patent, 245440, Class 12d, issued May 15, 1910. Filter for viscous liquids.
- BOISSON—French Patent, 436555. Filter for cellulose solutions.
- HARTOGS—German Patent, 257144, Class 29a, issued May 15, 1912. Filter for cellulose solutions.
- BERNSTEIN—French Patent, 424796. Process and apparatus for removing air from spinning solutions.
- THILMANY—German Patent, 317869, Class 29a, issued Feb. 20, 1919. Device for removing air from viscous solutions.
- TOPHAM—German Patent, 138507, Class 29b, May 21, 1901. Device for regulating the flow of viscous fluids.
- KUTTNER—French Patent, 450906. Spinning pump for producing filaments.

The following patents cover the construction and cleaning of spinnerettes:

- BERNSTEIN—German Patent, 216391, Class 29a, issued Feb. 6, 1909. Spinnerette for Rayon filaments.
- REUTS AND EILFELD—German Patent, 221572, Class 29a, issued June 30, 1909. Spinnerette with adjustable apertures.
- WORGERER—U. S. Patent, 988424. Spinnerette for Rayon filaments.
- FRANKE AND MILLER—German Patent, 250595, Class 29a. Spinnerette with enlargement.
- GUADAGNI—British Patent, 30306—1910. An improved spinnerette.
- LATAPIE—French Patent, 431096. Spinnerette for Rayon filaments.
- BOISSON—French Patent, 436556. Spinnerette for making lustrous filaments.
- BUFFARD—French Patent, 442630. Multiple aperture spinnerette.
- BUFFARD—French Patent, 442631. Wire system of making spinnerettes.
- BURILL—French Patent, 442632. Spinnerette.

- GIRARD & BUFFARD—French Patent, 445783. Spinnerette.
- CRIGGAL—British Patent, 18965—1912. An improved spinnerette for making filaments from cellulose solutions.
- LAROCHE—French Patent, 459849. A multi-aperture spinnerette.
- GLANZFÄDEN, A.G.—German Patent, 310743, Class 29a, issued Dec. 4, 1917. Spinnerette for making filaments.
- DENIS—German Patent, 263786, Class 29a, issued Feb. 11, 1913. Process for making and cleaning spinnerettes.

SPINNING PROCESSES AND MACHINES

- FREHLENERT—German Patent, 96208, Class 76, issued Feb. 10, 1897; German Patent, 101844, Class 76, issued Dec. 10, 1897; German Patent, 102573, Class 76, issued Dec. 10, 1897; German Patent, 143763, Class 29b, issued April 10, 1902; German Patent, 148038, Class 29b. These cover devices, methods and apparatus for spinning and also gathering the threads.
- TOPHAM—British Patent, 23157—1900. Centrifugal spinning pot.
- THIELE—German Patent, 133427, Class 29a, issued Mar. 22, 1901; German Patent, 148889, Class 29b, issued Dec. 25, 1902; German Patent, 178942, Class 29b, issued Oct. 27, 1905. Cover spinnerettes, arrangement of baths, collecting bobbins, etc.
- COCHINS—German Patent, 163293, Class 29b, issued April 15, 1902. An arrangement for generating and collecting Rayon filaments.
- SOCIÉTÉ LINKMEYER—German Patent, 168830, Class 29a. Spinning process and spinnerette.
- HÖINBERG—Belgian Patent, 168556, Feb. 17, 1903. Method and device for imparting an exceptional lustre.
- RYON AND WAITE—U. S. Patent, 732784. Device for regulating the pressure on the spinning piston.
- COOLEY—U. S. Patent, 745276. Method for imparting lustre to Rayon filaments by exposing same to an electrostatic discharge when they are generated.
- GRANQUIST—German Patent, 111333, Class 76, issued Jan. 5,

1899. An arrangement of special joint and angle for the spinnerette holder so that it can be turned in any direction.
- GOCHER O'LMUHLE—German Patent, 186203, Class 29a, issued Aug. 13, 1905; also Swiss Patent, 39711. Manifolds, joints, etc., for spinnerettes and spinnerette arms.
- MERTZ—French Patent, 364912. Spinning machine for Rayon filaments.
- FRIEDRICH—German Patent, 172264, Class 29a, issued Sept. 18, 1904; also German Patent, 172265, Class 29a, issued Sept. 8, 1904. Arrangement for spinning Rayon filaments separating same from the coagulating bath and winding them.
- LINKMEYER—German Patent, 222131, Class 29a, issued Jan. 23, 1906. Spinnerette arrangement for making artificial filaments.
- LE CLAIRE—French Patent, 359026. Rotating spinnerette.
- CUNTZ—French Patent, 383411. Process for making cellulose filaments from solutions.
- DREAPER—British Patent, 13868—1907; and British Patent, 21872—1908. Improved devices for making Rayon filaments.
- CHANDELON—French Patent, 394009. Arrangement for producing artificial lustrous filaments.
- CROMBIE—French Patent, 405782; also CROMBIE & SCHUBERT, French Patent, 409387. Apparatus for generating filaments from solutions.
- BORZYKOWSKI—German Patent, 248349, Class 29a, issued Sept. 16, 1910. Spinning machine for artificial fibres.
- HARTOGS—German Patent, 237744, Class 29b, issued Aug. 19, 1910. Process for making artificial fibres by generating them as usual and passing them through various solutions.
- HARTOGS—German Patent, 247418, Class 29b, issued July 13, 1911. Process and apparatus for making hollow filaments.
- COURTAULDS, LTD. & WILSON—British Patent, 17495—1914. Process and apparatus for making hollow filaments from cellulose solutions.
- IIUBNER—British Patent, 14599—1910. Process and apparatus for making filaments from cellulose.
- ELSASSER—German Patent, 244375, Class 29a, issued Nov. 19, 1910. Spinning machine for artificial fibres and method of cross-winding same on a reel.

- MILLER & FRANKE—British Patent, 4078—1911; also British Patent, 2222—1912. Improved spinning machines.
- LINKMEYER—German Patent, 249002, Class 29a, issued June 17, 1911. Device for twisting Rayon filaments as generated by means of a rotating spinnerette.
- PELLERIN—French Patent, 442022. Processes and devices for making filaments and formed articles from cellulose solutions.
- PING—British Patent, 22635—1911. An improved method for making filaments from viscous fluids.
- MEWES—German Patent, 252841, Class 29a, issued Oct. 20, 1910; German Patent, 276082, Class 29a, issued Nov. 13, 1909; German Patent, 288667, Class 29a, issued July 23, 1914. Cover process and devices for generating filaments from viscous solutions.
- WHITNER—U. S. Patent, 1115777. Apparatus for making artificial filaments.
- ALTHOUSE—U. S. Patent, 1202766. Device for making filaments.
- MARTIN & VENNIN—French Patent, 461432. Improved spinning pot which can be rapidly changed.
- VILAN AND SOCIÉTÉ LA SOIE ART. DU NORD—French Patent, 465322. Machine for spinning and twisting filaments made from viscous solutions.
- COURTAULDS, LTD. AND CLAYTON—French Patent, 481399. An improved spinning machine.
- MANCELIN—French Patent, 469890. Tubes for thread guides.
- COURTAULDS—British Patent, 104225. A guide for Rayon filaments.
- DUBOT—British Patent, 126263. Filter and tube guide for Rayon filaments.

The following patents cover processes and devices for spooling, reeling and twisting:

- ROHRENS—French Patent, 364269. Glass cylinder for spinning Rayon.
- VEREINIGTE GLANZSTOFF FABRIKEN, A. G.—German Patent, 236585, Class 76d, issued Feb. 24, 1910. Gathering drum for Rayon filaments.

- VEREINIGTE GLANZSTOFF FABRIKEN, A. G.—German Patent, 239821, Class 76d, issued May 26, 1910. Improvement on above.
- VEREINIGTE GLANZSTOFF FABRIKEN, A. G.—German Patent, 239822, Class 76d, issued May 26, 1910. Improvement on above.
- DINGER—German Patent, 253371, Class 29a, issued April 22, 1911. Reel for stretching artificial fibres.
- GIRARD—French Patent, 451913. Winding device by means of which it is claimed to increase the elasticity of artificial filaments.
- MANQUAT—British Patent, 12710—1912. An improved machine for winding Rayon filaments.
- SOCIÉTÉ ANONYME DES CELLULOSES PLANCHON—British Patent, 13360—1913. An improved spinning machine.
- BURILL—French Patent, 442593. Spool and spool carrier.
- KUTTNER—French Patent, 450818. Spool for use in making Rayon threads.
- ADOLFF—French Patent, 466210. Spool for winding Rayon.
- MANQUAT—French Patent, 440965. Spool carrier for Rayon spinning frames.
- RHEMISCHE KUNSTSEIDE FABRIK, A. G.—German Patent, 218586, Class 29a, issued July 15, 1908. Machine for winding off Rayon threads from standing spools.
- SOCIÉTÉ ANONYME FABRIQUE DE SOIE ART. DE TUBIZE—French Patent, 370717. Reeling machine for Rayon threads.
- MERTZ—Swiss Patent, 34742. Spooling machine.
- FONGENOL—French Patent, 337693. Device for reeling off Rayon.
- WEERTZ—British Patent, 10211—1910. Reeling device.
- FOX & MEYERS—British Patent, 1022—1911. Improved device for handling Rayon, especially reeling and reel control.

The following patents relate to the arts of washing and drying:

- FRIEDRICH—German Patent, 178410, Class 29a, issued June 16, 1905. Process and apparatus for washing and drying.
- GOCHER O'LMUILE—German Patent, 118910, Class 29a, issued

Nov. 15, 1905. A ribbed winding spool with cross-winding device to permit subsequent washing and drying in the spool.

HENCKEL VON DONNERSMARCK—German Patent, 187090, Class 29a, issued May 3, 1905. Process and machinery for washing and treating spooled yarns especially such as are made from cellulose solutions.

KUTTNER—German Patent, 271656, Class 29a, issued July 21, 1912. Device for washing spooled Rayon.

COURTAULDS & CLAYTON—British Patent, 9067—1913. Improved processes and machinery for bleaching, dyeing and washing of yarn or silk hanks.

The following patents relate to various arts such as water-proofing, parchmentizing, lustre removal, opaquing, weighting, finishing, etc.:

BARDY—French Patent, 313464. Parchmentizing process for increasing Rayon fibre strength by treating with sulphuric acid.

ESCHALIER—French Patent, 374724. Process for increasing the strength of Rayon threads.

ESCHALIER—French Patent, 9904, also French Patent, 10760. Process for strengthening cellulose and albuminous bodies by treating with formaldehyde.

FRIEDRICH—French Patent, 369957. Process for increasing the strength and water resistance of Rayon threads.

GEBAUER—German Patent, 232605, Class 29b, issued Jan. 10, 1908. Process for increasing the elasticity and strength of Rayon filaments.

BURGEON—French Patent, 434602. Process of opaquing Rayon threads by the use of petroleum.

SOCIÉTÉ LA SOIE ARTIFICIELLE—French Patent, 477655. Process for increasing strength of Rayon threads by treating same with trioxymethylen.

CHESNAR'S—French Patent, 463693. Process for making and strengthening of Rayon threads.

FESSMAN—German Patent, 316045, Class 29a, issued Nov. 26, 1918. Process for increasing the strength of Rayon threads by calendering.

- MEYER—German Patent, 314968, Class 8c. Process for strengthening Rayon threads by treating them with metallic salt solutions and subsequently with soap solutions.
- BORZYKOWSKI—German Patent, 262253, Class 29b, issued July 12, 1912. Process for making lustreless Rayon filaments by treating same with alkalis containing metallic oxides soluble therein.
- WAGNER—German Patent, Class 29b, issued June 5, 1901. Process for opaquing Rayon fibres.
- CULP—German Patent, 274044, Class 8m. Process for thickening natural and artificial fibres without weighting.
- GAS GLUHLICHT, A.G.—British Patent, 116103. Process for weighting Rayon filaments.
- COMPAGNIE FRANÇAIS DES APPLICATIONS DE LA CELLULOSE—French Patent, 417599. Process for finishing cellulose bodies.
- HUBNER—British Patent, 19166—1910. Process for finishing Rayon with glycerine.
- FRIEDEL—French Patent, 463160. Process for strengthening Rayon by stretching under heat.
- COURTAULDS AND LINFOOT—British Patent, 18556—1914. Improved process for handling Rayon and machinery necessary therefor.

U. S. PATENTS, 1916

- DREYFUSS—U. S. 1181858-60, issued May 2. Celluloid substitutes.
- DREYFUSS—U. S. 1181857, issued May 2. Cellulose acetates.
- LEDERER—U. S. 1195040, issued Aug. 15. Celluloid substitutes.
- LINDSAY—U. S. 1199799, issued Oct. 3. Celluloid substitutes.
- CHRISTOPHE—U. S. 1184323, issued May 23. Making cellulose threads.
- MORK—U. S. 1193178, issued Aug. 1. A cellulosic composition.
- BERL AND ISLER—U. S. 1188718, issued June 27. Nitrocellulose spinning solutions.
- CHARDONNET—U. S. 1209133, issued Dec. 19. Spinning machine for artificial silk.

PATENTS, 1917

DREYFUSS—U. S. 1242783, issued Oct. 9. Celluloid substitutes.

DREYFUSS—U. S. 14388, issued July 31 (reissue). Cellulose acetate.

DREYFUSS—U. S. 1217722, issued Feb. 27. A process for treating cellulose acetates in order to alter their solubility.

LINDSAY—U. S. 1226349-3, issued May 15. Acetyl cellulose plastics and solvents therefore; also U. S. 1244347-9, issued Oct. 23. Solvents for acetyl cellulose; also U. S. 1244107-8, issued Oct. 23. Methods of producing flowable cellulose acetate compounds.

OSTENBERG—U. S. 1242030, issued Oct. 2. Cellulose solutions.

LINFOOT—U. S. 1229101, issued June 5. Apparatus for treating artificial silk threads.

CLAYTON—U. S. 1240675, issued Sept., 1912. Apparatus for making artificial silk.

CLAYTON—U. S. 1224071, issued April 24. Thread guide for artificial silk.

KISHI—U. S. 1231172, issued June 26. Method of producing artificial silk.

KATZ—U. S. 1251237, issued Dec. 25. Making Viscose.

BIROLI—U. S. 1226178, issued May 15. Producing threads from Viscose.

PATENTS, 1918

DREYFUSS—U. S. 1280974-5, issued Oct. 8. Making cellulose acetate of various solubilities.

RUPPERT—U. S. 1263119, issued April 16. Making cellulose acetate.

DREYFUSS—U. S. 1278885, issued Sept. 17. Making cellulose acetate.

KOETCHET—U. S. 1258913, issued Mar. 12. Manufacture of cellulose acetate.

EISELEN & MORK—U. S. 1275884, issued Aug. 13. Preparation of cellulose acetate.

DREYFUSS—U. S. 1286712, issued Nov. 12. Transforming cellulose acetate.

FLACK—U. S. 1280961, issued Oct. 8. Apparatus for draining, washing and conveying cellulose nitrate.

GLORN & WILSON—U. S. 1279328-30, issued Sept. 17. Manufacture of cellulose compounds.

BORZYKOWSKI—U. S. 1260508, issued Mar. 26. Production of articles from Viscose.

PATENTS, 1919

KESSLER—U. S. 1303563, issued May 3. Cellulose acetate composition.

CLARKE—U. S. 1309980, issued July 15. Cellulose ester composition.

GOLDSMITH—U. S. 1298199, issued Mar. 25. Cellulose ester dope.

POLOTSKY—U. S. 1296847, issued Mar. 11. Cellulose ester with over 20 per cent fatty acid.

CLARKE—U. S. 1309981, issued July 15. Cellulose nitrate composition.

MERSEREAU—U. S. 1308803, issued July 8. Cellulose solvent.

CLAYTON—U. S. 1301652, issued April 22. Treating cellulose.

DU PONT—U. S. 1301409, issued April 22. Nitrocellulose dryer.

WALTHER—U. S. 1292544, issued Oct. 8. Precipitation of Viscose threads.

PATENTS, 1920

SEEL—U. S. 1342603, issued June 8. Cellulose acetate composition.

DREYFUSS—U. S. 1353384-5, issued Sept. 21. Manufacture of compositions, preparations or articles having a basis of cellulose acetate.

TRYER—U. S. 1339728, issued May 11. Production of cellulose acetate solutions.

LINDSAY—U. S. 1338661, issued April 27. Making acetyl cellulose.

DE CEW—U. S. 1354731, issued Oct. 5. Producing cellulose fibres.

HESSE—U. S. 1341745, issued June 1. Making tubular products from cellulose or cellulose compounds.

OSTENBERG—U. S. 1355415, issued Oct. 12. Preparing solutions of cellulose.

FURNESS—U. S. 1338648, issued April 27. Method and apparatus for winding artificial silk.

LILLIENFELD—U. S. 1355985, issued Oct. 19. Manufacture of Viscose.

PATENTS, 1921

MILES—U. S. 1394752, issued Oct. 25. Treating cellulose acetate and products thereof.

DREYFUSS—U. S. 1395401, issued Nov. 1. Making solutions of cellulose acetate.

CONLEY & STILLWELL—U. S. 1371300, issued Mar. 15. Treating regenerated cellulose articles.

LILLIENFELD—U. S. 1379351, issued May 24. Cellulose xanthate solutions and products.

KRAFT—U. S. 1389834, issued Sept. 6. Cellulose solution flow controller.

CLAYTON—U. S. 1366163, issued Jan. 8. Apparatus employed in the manufacture of artificial silk.

PRIMS—U. S. 1371113, issued Mar. 8. Apparatus for spinning artificial silk.

LANCE—U. S. 1398525, issued Nov. 29. Artificial silk.

RITTENHOUSE—U. S. 1367893, issued Feb. 8. Machine for spinning artificial silk.

BRONNERT—U. S. 1393197-9, issued Oct. 11. Manufacture of artificial silk.

BRONNERT—U. S. 1387882, issued Aug. 16; U. S. 1374718, issued April 12; U. S. 1376672, issued May 3. Manufacture of artificial silk.

KITSEE—U. S. 1389317, issued Aug. 30. Method and means of producing artificial silk.

CLAYTON—U. S. 1366162, issued Jan. 18. Process and apparatus for spinning artificial silk.

STEIMMIG—U. S. 1399587, issued Dec. 16. Method for precipitating Viscose.

PATENTS, 1922

DREYFUSS—U. S. 1440006, issued Dec. 26. Cellulose acetate composition.

- BRIGGS—U. S. 1425364, issued Aug. 8. Treatment of cellulose acetate products.
- PUTNAM & KIRST—U. S. 1406224, issued Feb. 24. Cellulose acetate solution.
- ESSELEN & MORK—U. S. 1425580, issued Aug. 15. Cellulose derivatives and preparing same.
- MITCHERLING—U. S. 1435650, issued Nov. 14. Preparation of Viscose solutions of cellulose for the production of films, filaments or threads.
- VENTER—U. S. 1412763, issued April 11. Method and machine for reducing cellulose to fibres and transforming same to a liquid state.
- CLAYTON—U. S. 1406153, issued Feb. 7. Apparatus employed in the manufacture of artificial silk.
- CLAYTON—U. S. 1429127, issued Sept. 12. Apparatus for and method of manufacturing artificial silk.
- CLAYTON—U. S. 1425368, issued Aug. 8. Apparatus for spinning artificial silk.
- SNYDER—U. S. 1423041, issued July 18. Composition for the treatment of artificial silk.
- SINKWITZ—U. S. 1427238, issued Aug. 29. Device for throwing, washing and reeling spooled artificial silk.
- BRONNERT—U. S. 1437491, issued Dec. 5. Drying artificial silk.
- JUER—U. S. 1407280, issued Feb. 21. Automatic regulator for artificial silk machines.
- BRONNERT—U. S. 1422412, issued July 11. Manufacture of artificial silk.
- BRONNERT—U. S. 1426953, issued Aug. 22. Manufacture of artificial silk.
- DREAPER—U. S. 1437340, issued Nov. 28. Process and apparatus for the manufacture of artificial silk and the like.
- CLAYTON—U. S. 1417455-6, issued May 23. Spinning box for artificial silk.
- LEHNER—U. S. 1437899, issued Dec. 5. Water-driven spinning cup device for artificial silk.
- LUFT—U. S. 1407696, issued Feb. 28. Manufacture of artificial goods from Viscose.
- BRONNERT—U. S. 1419714, issued June 13. Manufacture of Viscose silk.

DREAPER—U. S. 1418135, issued May 30. Manufacture of Viscose solutions.

LUFT—U. S. 1404535, issued Jan. 24. Treatment of artificial goods made from Viscose.

PATENTS, 1923

KESSLER & SEASE—U. S. 1466401, issued Aug. 29. Making cellulose acetate.

NEBEL—U. S. 1478137, issued Dec. 18. Making cellulose acetate.

BASSET—U. S. 1466329, issued Aug. 28. Acetylizing cellulose.

LILLIENFELD—U. S. 1441989, issued Jan. 9. Production of cellulose ethers.

FARROW—U. S. 1467107, issued Sept. 4. Process for making alkali cellulose.

CALLIMACHI—U. S. 1449380, issued March 27. Manufacture of threads, filaments, strips and films from cellulose.

DITMAN—U. S. 1456540, issued May 29. Regenerated cellulose material and method of making same.

CONLEY & STILLWELL—U. S. 1467265, issued Sept. 4. Regenerating cellulose.

DELAHAYE—U. S. 1470711, issued Oct. 16. Manufacturing Viscose for the purpose of making artificial silk and the like not liable to lose their resistance by contact with water.

MEIGS—U. S. 1471699, issued Oct. 23. Artificial silk and making the same.

BINDSCHEDLER AND JUER—U. S. 1441203-5, issued Jan. 9. Manufacturing artificial silk and other products from nitro-cellulose.

STEVENSON—U. S. 1478926, issued Dec. 25. Manufacture of artificial silk from acetyl cellulose.

BRONNERT—U. S. 1463793, issued Aug. 7, also U. S. 1464805, issued Aug. 14. Manufacture of artificial silk. U. S. 1458389, issued June 12, and U. S. 1471513, issued Oct. 23. Manufacture of Viscose.

KITSEE—U. S. 1457977, issued June 5. Producing artificial silk.

SNYDER—U. S. 1474560, issued Nov. 20. Treatment of artificial silk.

PATENTS, 1924

- SEEL—U. S. 1494816, issued May 20. Manufacturing cellulose acetate.
- WEBB—U. S. 1514274, issued Oct. 4, also 1516255, issued Nov. 18. Manufacturing cellulose acetate.
- BERL—U. S. 1484004, issued Feb. 19. The production of alkyl cellulose and products containing same.
- DREYFUSS—U. S. 1501207, issued July 15, also U. S. 1502379, issued July 22. The manufacture of cellulose derivatives.
- LILIENFELD—U. S. 1505043, issued Aug. 12. A cellulose ether and method of making same.
- CARROLL—U. S. 1500366, issued July 8. A cellulose ether composition.
- ERENTHAL—U. S. 1509273, issued Sept. 23. A method of obtaining easily-bleached cellulose fibres.
- DREYFUSS—U. S. 1501206, issued July 15, also U. S. 1508928, issued Sept. 16. Plastics containing cellulose acetate.
- HUBERT—U. S. 1517627, issued Dec. 2. Making artificial silk.
- GREEN AND SAUNDERS—U. S. 1483797, issued Dec. 12. Dyeing and printing acetate silk and materials containing same.
- BASSETT & BAUMIGAN—U. S. 1497321, issued June 10. Making artificial silk and similar products.
- DREAPER—U. S. 1515556, issued Nov. 11. Manufacture of artificial silk.
- HOLKEN—U. S. 1493545, issued May 13. Method for making artificial silk by the stretch spinning process.
- DREYFUSS AND LEONARD—U. S. 1492594, issued May 6. Spinning jet or nozzle for making artificial silk.
- DREAPER—U. S. 1489199, issued April 15. Spinning and twisting strands of artificial silk and other yarns or threads.
- COLLING BONNE—U. S. 1497068, issued June 10. Artificial silk.
- VAN KREYTEN—U. S. 1510810, issued Oct. 7. Purifying Viscose and similar solutions of cellulose.
- HUTTINGER—U. S. 1502101, issued July 22. Manufacturing Viscose.

PATENTS, 1925

- CARROLL—U. S. 1560542, issued Nov. 10. Cellulose acetate composition.
- CLARKE—U. S. 1548932, issued Aug. 11. Cellulose acetate composition.
- ELLIS—U. S. 1545819, issued July 14. Dyeing or coloring objects made of cellulose acetate.
- SEEL—U. S. 1536311, issued May 5. Intermediate product in the manufacture of cellulose acetate.
- SEEL—U. S. 1544944, issued July 7. Making cellulose acetate.
- SULZER—U. S. 1560620, issued Nov. 10. Manufacturing cellulose acetate.
- SEASE—U. S. 1546679, issued July 21. Producing cellulose acetate.
- FARROW—U. S. 1560554, issued Nov. 10. Treating cellulose acetate re-action mixtures.
- YOUNG—U. S. 1522852, issued Jan. 13. Solvent for cellulose acetate.
- FARROW—U. S. 1521876, issued Jan. 6, also U. S. 1557147, issued Oct. 13. Treating cellulose acetate.
- ZDANOWICH—U. S. 1528810, issued March 10. Manufacture of cellulose acetates.
- LINDSAY—U. S. 1538859, issued May 19. Cellulose composition and process.
- ZIMMERMAN—U. S. 1523742, issued Jan. 20. The manufacture of a cellulose compound indifferent to substantive colors.
- CLANCY—U. S. 1544809-10, issued July 7. Treating cellulose compounds.
- BADER & DICKIE—U. S. 1536052, issued May 5. Manufacture of compositions of cellulose derivatives.
- CLARKE—U. S. 1552795, issued Sept. 8. Cellulose ester composition.
- HOSKINS—U. S. 1524133, issued Jan. 27. Forming cellulose ester materials.
- PITMAN—U. S. 1535438, issued April 28. Making a cellulose ester of reduced viscosity.
- METZGER—U. S. 1532427, issued April 7. Treatment for dyeing cellulose esters.

- BINDSCHIEDLER AND JUER—U. S. 1551791, issued Sept. 1. Manufacture of artificial silk and other products from cellulose acetate.
- GRILLET—U. S. 1566398, issued Dec. 22. Manufacture of cellulose esters in a solvent.
- PIFFNER—U. S. 1529712, issued Mar. 17. Chemically coating sheets of metal with cellulose esters.
- CARROLL—U. S. 1552792, issued Sept. 8, also U. S. 1552794, issued Sept. 8. Cellulose ether composition.
- LEAVER—U. S. 1528219, issued March 3. Regenerating cellulose from Viscose.
- LEAVER AND HUMBOLT—U. S. 1528218, issued March 3. Manufacturing pure cellulose from wood.
- DREYFUSS—U. S. 1546211, issued July 14. Manufacturing products containing cellulose.
- JUER—U. S. 1562093, issued Nov. 17. Nitrating cellulose.
- ALTWEGG—U. S. 1543310, issued June 23. Preliminary treatment for cellulose prior to esterification.
- BRANDENBERGER—U. S. 1544885, issued July. Producing hydrated cellulose.
- BASSET—U. S. 1560965, issued November 10. Spinning artificial silk and other filaments from cellulose materials.
- BRIGGS AND YORKE—U. S. 1541104, issued June 9. Apparatus for the production of artificial silk.
- DREYFUSS—U. S. 1566384, issued Dec. 22. Manufacture of artificial silk and the like from cellulose derivatives.
- KEMPF AND HARTMAN—U. S. 1549364, issued Aug. 11. Apparatus for spinning artificial silk.
- BRANDENBERGER—U. S. 1548864, issued Aug. 11. Manufacture of Viscose films.
- HUBER AND ECKERT—U. S. 1550360, issued Aug. 11. Formed Viscose.
- HUMBOLDT—U. S. 1562885, issued Nov. 24. Preparing Viscose solutions.
- STEVENSON—U. S. 1556174, issued Oct. 6. Purification of Viscose solutions.
- HARTOGS—U. S. 1534382, issued April 21. Spinning Viscose.

CHEMICAL FOUNDATION

A number of patents concerning the manufacture of Rayon are controlled by the Chemical Foundation. These may be acquired on paying a license issue fee of \$100 per patent and a maximum of 5 per cent royalty on sales based on the value of goods manufactured thereunder. For the reader's information extracts are hereinafter given outlining the purposes and structure of the Chemical Foundation:

The name of the Corporation is "THE CHEMICAL FOUNDATION, INCORPORATED."

The nature of the business of the Corporation and the objects and purposes proposed to be transacted, promoted or carried on by it are as follows: to wit:

(a) To acquire by purchase from the Alien Property Custodian, under the provisions of an Act of the Congress of the United States, known as the "Trading with the Enemy Act" (Act October 6, 1917, as amended by Act of March 28, 1918, and further amended by Act of November 4, 1918) patents, and applications therefor, trade-marks, choses in action, and rights and claims of every character and description, owing or belonging to or held for, by, on account of, or on behalf of, or for the benefit of, an enemy or ally of enemy, as defined by said Act, which the Alien Property Custodian is authorized by said Act, and amendments thereto, to require and seize, and to sell and convey, and also to acquire from any person, firm or corporation any and all letters patent, and applications therefor, trade-marks, and similar rights, granted by the United States, or any other country or government, licenses and the like, or any other interest therein, or any inventions which may seem capable of being used for or in connection with any of the objects or purposes of said corporation, and to hold any such property and rights, so acquired, in a fiduciary capacity for the Americanization of such industries as may be affected thereby, for the exclusion or elimination of alien interests

hostile or detrimental to the said industries, and for the advancement of chemical and allied science and industry in the United States.

(b) In furtherance of the above objects and purposes the Corporation may grant non-exclusive licenses only, to make, use, and sell the inventions covered by any patents owned or controlled by it to the United States of America, upon such terms as the Board of Directors may determine, and also upon reasonable and equal terms and without advantage, as between licensees, to the following: (1) Natural persons, citizens of the United States, (2) Copartnerships, all the members of which are citizens of the United States, and (3) Corporations organized under the laws of the United States, or of any state, territory or dependency of the United States, of which not less than three-fourths of the capital stock, and the beneficial interest therein, is owned by stockholders who are citizens of the United States, and who were not, prior to the "end of the war," as used in the "Trading with the Enemy Act," enemies, or allies of enemies, as defined by said Act, and the amendments thereto;

The Board of Directors may refuse to issue any license or may revoke any license granted by the Corporation and may prescribe the terms and conditions of said licenses. It shall be the duty of the Corporation to defend and enforce the rights acquired by it, and to protect the rights of its licensees under any licenses granted by it.

(c) To purchase, or otherwise acquire, such personal property of every kind and description within and without the State of Delaware, and in any part of the world, suitable, necessary, useful or advisable in connection with any or all of the objects hereinbefore set forth.

(d) To do each and every thing necessary, suitable, useful or advisable for the accomplishment of any one or more of said objects, or which shall at any time appear to be conducive to or expedient for the benefit of such Corporation in connection therewith.

(e) In general, but in connection with the foregoing, said Corporation shall have and exercise all the powers conferred by the laws of the State of Delaware upon business corporations, it being hereby expressly provided that the

foregoing enumeration of specific powers shall not be held to limit or restrict in any manner such general powers.

(f) To do each and all things above set forth to the same extent and as fully as a natural person might do or could do in the State of Delaware or in any other state, country or place:

The total authorized capital stock of the Corporation is Five Hundred Thousand Dollars (\$500,000), divided into five thousand (5000) shares of the par value of One Hundred Dollars (\$100) each.

Of said authorized capital stock four thousand (4000) shares, amounting to Four Hundred Thousand Dollars (\$400,000), shall be non-voting preferred stock (except for amendment of the Charter, as hereinafter provided) and one thousand (1000) shares, amounting to One Hundred Thousand Dollars (\$100,000), shall be common stock.

The preferred stock shall entitle the holders thereof to receive, when and as declared, out of the surplus or net earnings of the Corporation, a fixed cumulative dividend at the rate of, but never exceeding, six per cent (6%) per annum, payable quarterly on such dates as the Directors may determine, which dividend shall run from the date of the issue of said preferred stock, and shall be paid or set apart before any dividend shall be set apart or paid on the common stock.

The common stock shall entitle the holders thereof to receive, when and as declared, out of the surplus or net earnings of the Corporation, a dividend at the rate of, but never exceeding, six per cent (6%) per annum, but no such dividends shall be payable on the common stock until all cumulative dividends on the preferred stock at the above rate, up to the date of the declaration of such common stock dividends, shall have been paid or set apart.

In the event of any liquidation or dissolution or winding up of the Corporation, whether voluntary or involuntary, the preferred stock shall entitle the holders thereof to be paid in full the par amount of their shares, with all unpaid accumulated dividends thereon to the date of such payment, before any amount shall be paid to the holders of the common stock.

The preferred stock shall be subject to redemption as a whole at One Hundred Dollars (\$100) per share, and accumulated dividends thereon, on the first day of January, 1921, or on the first day of January in any year thereafter, in such manner as the Board of Directors shall determine; provided that whenever the accumulated surplus of the Corporation amounts to one hundred per cent (100%) of the total issued and outstanding preferred and common stock of the Corporation, the Board of Directors shall redeem all the issued and outstanding preferred stock. After the full redemption of the preferred stock, the net earnings of the Corporation, over and above such amounts as may be necessary for the purpose of working capital, shall be used and devoted to the development and advancement of chemistry and allied sciences, in the useful arts and manufactures in the United States, in such manner as the Board of Directors may determine.

The holders of the common stock shall have the sole right to vote at all meetings of the stockholders, and the holders of the preferred stock shall have no voting power, except for the purpose of the amendment of the Charter. None of the owners or holders of the preferred or common stock of this Corporation shall sell, assign, or transfer any such stock except with the approval of the Board of Directors.

From time to time the common and preferred stock may be increased according to law.

The Board of Directors shall, from time to time, fix and determine the uniform license fee or royalty that shall be paid by the persons, firms or corporations mentioned in paragraph (b) of Article 3 of this certificate, and the license fee or royalty so fixed shall be binding and conclusive on the Corporation and upon all of its licensees.

It is to be noted that all earnings received from licenses of the Foundation's patents, in excess of the 6% dividend on the preferred and common shares, must be devoted to the development of manufacturing science. Contrary to general opinion, as gleaned from its charter, the purpose of the Chemical Foundation is institutional and for the benefit of American industry.

The following are the numbers of the patents controlled by the Foundation and are classified by processes:

NITROCELLULOSE RAYON

- 1093012—Process for the preparation of nitrocellulose.
- 1168164—Derivatives of cellulose containing the residue of an organic acid and nitrogen and process of making same.
- 1248933—Process of utilizing the wash-water of the manufacture of nitrocellulose.

CUPRA-AMMONIUM RAYON

- 945559—Process of producing solutions for spinning artificial threads and the like.
- 962769—Method of manufacturing cellulose structures.
- 962770—Process of producing durable solutions for spinning and other purposes.
- 979013—Process of manufacturing masses for use in making artificial threads and the like.
- 983139—Manufacture of filaments, films and other cellulose products from cellulose solutions.
- 988430—Process of manufacturing artificial threads.
- 1000827—Process of making salts of hydrated cupric oxid.
- 1022097—Process of manufacturing fine artificial threads.
- 1023548—Method of recovering ammonia in the cupra-ammonium cellulose precipitation.
- 1030251—Process for producing cellulose products.
- 1034235—Process of manufacturing artificial threads.
- 1049201—Process for recovering copper from the wash liquors employed in the cupra-ammonia cellulose process.
- 1062106—Process for producing cellulose formations.
- 1064260—Process for the manufacture of cellulose solutions.
- 1066785—Manufacture of artificial silk threads from cellulose.
- 1106077—Process for the production of shaped articles from copper-ammonium cellulose solution.
- 1421707—Process of preparing a permanent and spinnable solution in the cupra-ammonia process,

VISCOSE RAYON

- 960100—Compound for producing silk-like effects.
- 980648—Method of producing stable soluble cellulose derivatives from Viscose.
- 1073891—Process of manufacturing artificial lustrous threads, bands and filaments.
- 1074881—Dry Viscose in a granular, soluble and stable condition and process of preparing the same.
- 1102237—Process for the production of threads, films or plates.
- 1121605—Method of manufacturing a Viscose solution from wood-cellulose.
- 1121903—Process of manufacturing artificial lustrous threads, etc.
- 1200774—Treatment of cellulose derivatives.
- 1292544—Process for the precipitation of Viscose for the production of artificial threads and other structures.
- 1355985—Process for the manufacture of Viscose.
- 1379351—Process of making cellulose xanthogenate solutions and product produced.
- 1414070—Process for the manufacture of lustrous threads from crude Viscose by means of warm mineral acids.
- 1428246—Process for producing spun material resembling wool, cotton, or chappe from Viscose solutions.

CELLULOSE ACETATE RAYON

- 922340—Manufacture of objects from cellulose acetate.
- 954310—Process of producing acetyl-cellulose-coated material.
- 999236—Process for preparing cellulose esters in definite forms.
- 1028748—Filaments and other products obtained from cellulose compounds.
- 1069445—Process for acetylating cellulose and its products of transformation.
- 1090074—Compounds or derivatives of cellulose and process of obtaining the same.
- 1109512—Process of making a cellulose acetate soluble in ethyl acetate.
- 1173931—Process of producing coating compositions of acetyl cellulose,

- 1201260—Process for the manufacture of cellulose esters.
1241995—Modifying acetyl cellulose.
1263119—Cellulose acetate and a process of making same.
1296847—Process for making cellulose esters with over 20% of bound fatty acid.

CELLULOSE FORMATE RAYON

- 953677—Cellulose formate.
955082—Cellulose formate.
1029341—Transforming formyl esters of cellulose or solutions of the same into stable plastic solutions.
1046729—Process of producing formyl cellulose.
1055513—Production of Viscose cellulose solutions.
1061977—Process for the production of formyl celluloses.
1153596—Non-inflammable celluloid-like mass and process of production thereof.

OTHER FORMS OF RAYON

- 904269—Producing glossy or silky effects on fabrics and other material.
930874—Cellulose substitute.
942395—Method of improving textile fibres, threads, and fabrics.
973253—Method of producing incandescent mantles.

APPARATUS USED IN THE RAYON INDUSTRY

- 957460—Machine for spinning viscous liquids.
1020117—Process for imparting lustre to yarns, fabric and the like.
1209465—Apparatus for leaching and rinsing mercerized fabrics and recovering the lye.

MISCELLANEOUS PATENTS RELATING TO CELLULOSE ESTERS

- 902093—Process of separating cellulose esters from solutions.
1037158—Process of manufacturing substitutes for oils, caoutchouc, resins and the like.
1141510—Process of preparing solutions of cellulose.

- 1188376—Alkyl ethers of cellulose and process of making the same.
1217027—Film and process of producing same.
1217028—Manufacture of artificial textile material and process of producing same.
1350820—Alkyl ether of starches and similar carbohydrates and method of producing the same.
1414076—Spinning viscous liquids in flowing feeding liquids.

PATENTS RELATING TO WOOL SUBSTITUTES

- 1383742—Process for manufacturing a wool substitute from cellulose and similar solutions.
1428246—Process for producing spun material resembling wool, cotton, or chappe from Viscose solutions.

DYEING OF RAYON

- 961241—Dyeing acetyl cellulose.
979966—Process of dyeing acetyl cellulose.
981574—Treatment of acetyl cellulose to enhance its elasticity and its power of absorption of dyestuffs.
1002408—Art of dyeing acetyl cellulose.
1169267—Dyeing artificial silk.

CLEANSING AGENTS

- 1165498—Process of rendering tetrachlorid of carbon and other halogen hydrocarbons, or hydrocarbons soluble in dilute solutions of soap.

APPENDIX

TABLE 99. CONVERSION OF STATEMENTS OF CHEMICAL COMPOSITION

	Grains per U. S. Gallon (231 cu.in.)	Grains per British Gallon (277 cu.in.)	Parts per Hundred Thousand	Parts per Million
1 grain per U. S. gallon.....	1.000	1.20	1.71	17.1
1 grain per British gallon....	0.830	1.00	1.43	14.3
1 part per 100,000.....	0.580	0.70	1.00	10.0
1 part per 1,000,000.....	0.056	0.07	0.10	1.0

TABLE 100. CONVERSION TABLE OF HARDNESS FROM ENGLISH, FRENCH AND GERMAN DEGREES TO PARTS PER MILLION

	Parts per Million	Clark Degrees	French Degrees	German Degrees
Parts per million.....	1.0	0.07	0.10	0.56
Clark or English degrees....	14.3	1.00	1.43	0.80
French degrees.....	10.0	0.70	1.00	0.56
German degrees.....	17.8	1.24	1.78	1.00

NOTE.—English degrees of hardness, Clark scale, are equivalent to grains of calcium carbonate per imperial gallon, and are multiplied by 14.3 to give parts per million. French degrees of hardness represent parts per hundred thousand of calcium carbonate, and are multiplied by 10 to give parts per million. German degrees of hardness represent parts per hundred thousand of calcium oxide, and are multiplied by 17.8 to give parts per million of calcium carbonate.

USEFUL TABLES

WEIGHTS AND MEASURES

ENGLISH SYSTEM

AVOIRDUPOIS AND COMMERCIAL WEIGHTS

16 drams, or 437.5 grains	= 1 ounce, oz.
16 ounces, or 7000 grains	= 1 pound, lb.
28 pounds	= 1 quarter, qr.
4 quarters (English)	= 1 hundredweight, cwt.—112 lbs.
20 hundredweight	= 1 ton of 2240 lbs., gross or long ton
2000 pounds	= 1 net, or short, ton
2204.6 pounds	= 1 metric ton = 1000 kilos.
1 stone = 14 pounds; 1 quintal	= 100 pounds

SHIPPING TON—FOR THE MEASUREMENT OF CARGO

40 cubic feet =	{ 1 U. S. shipping ton 31.16 Imp. bushels 32.143 U. S. bushels
42 cubic feet =	{ 1 British shipping ton 32.719 Imp. bushels 33.75 U. S. bushels

TROY WEIGHTS

24 grains	= 1 pennyweight, dwt.
20 pennyweights	= 1 ounce, oz. = 480 grains
12 ounces	= 1 pound, lb. = 5760 grains
1 carat	= .3.168 grains = 0.205 gram

Troy weight is used for weighing gold and silver. The grain is the same in Avoirdupois, Troy, and Apothecaries' weights.

APOTHECARIES' WEIGHTS

20 grains	= 1 scruple
3 scruples	= 1 drachm, $\mathfrak{z}$ = 60 grains
8 drachms	= 1 ounce, $\mathfrak{z}$ = 480 grains
12 ounces	= 1 pound, lb. = 5760 grains

APOTHECARIES' MEASURES

60 minims (min.)	= 1 fluid drachm (fl. dr. or f $\mathfrak{z}$)
8 fluid drachms	= 1 fluid ounce (fl. oz. or f $\mathfrak{z}$)
20 fluid ounces	= 1 pint (O) +
8 pints	= 1 gallon (C) +

RELATIONS OF APOTHECARIES' MEASURES TO WEIGHTS

(All liquids to be measured at 62° Fahr.)

1 minim is the measure of	0.9115 grains of distilled water
1 fluid drachm " "	54.687 " " " "
1 fluid ounce " "	437.5 " " " "
1 pint " "	8750 " " " "
1 gallon " "	70000 " " " "

LINEAR MEASURE

12 inches = 1 foot	4 poles = 1 chain
3 feet = 1 yard	40 poles = 1 furlong
6 feet = 1 fathom	8 furlongs = 1 mile = 1760 yards
5½ yards = 1 rod pole, or perch	

SQUARE MEASURE

144 square inches = 1 square foot
9 square feet = 1 square yard
30.25 square yards or 272.5 sq. feet = 1 square rod
160 square rods or 4840 sq. yards or 43560 sq. feet = 1 acre
640 acres = 1 square mile

An acre equals a square whose side is 208.7 feet

CUBIC MEASURE

1728 cubic inches	= 1 cubic foot
27 cubic feet	= 1 cubic yard
1 cord of wood	= a pile 4 × 4 × 8 feet = 128 cubic feet
1 perch of masonry	= 16.5 × 1.5 × 1 foot = 24.75 cubic feet
1 cubic inch of water at 62° Fahr. weighs	252.286 grains
" " " " " " "	0.57665 oz. (av.)
" " " " " " "	0.036041 lb.
1 cubic foot " " " " "	996.458 oz. (av.)
" " " " " " "	62.2786 lb.
1 cubic yard " " " " "	0.75068 ton

CAPACITY MEASURE

LIQUID

4 gills	= 1 pint
2 pints	= 1 quart
4 quarts	= 1 gallon

RELATION OF CAPACITY, VOLUME, AND WEIGHT

1 pint	=	28.875 cubic inches
1 quart	=	57.75 cubic inches
1 gallon (U. S.)	=	231 cubic inches
1 gallon (English)	=	277.274 cubic inches
7.4805 gallons	=	1 cubic foot
1 gallon water at 62° Fahr.	weighs	8.3356 lbs.

DRY

2 pints	=	1 quart
8 quarts	=	1 peck
4 pecks	=	1 bushel
1 U. S. standard bushel (struck)	=	2150.42 cubic inches
0.80356 U. S. bushel (struck)	=	1 cubic foot

TABLE 101. EQUIVALENTS OF OUNCES IN DECIMALS OF THE POUND

Ozs.	Decimals	Ozs.	Decimals	Ozs.	Decimals	Ozs.	Decimals
	Pound		Pound		Pound		Pound
$\frac{1}{4}$	0.0156	$4\frac{1}{4}$	0.2656	$8\frac{1}{4}$	0.5156	$12\frac{1}{4}$	0.7656
$\frac{1}{2}$	0.0312	$4\frac{1}{2}$	0.2812	$8\frac{1}{2}$	0.5312	$12\frac{1}{2}$	0.7812
$\frac{3}{4}$	0.0468	$4\frac{3}{4}$	0.2968	$8\frac{3}{4}$	0.5468	$12\frac{3}{4}$	0.7968
1	0.0625	5	0.3125	9	0.5625	13	0.8125
$1\frac{1}{4}$	0.0781	$5\frac{1}{4}$	0.3281	$9\frac{1}{4}$	0.5781	$13\frac{1}{4}$	0.8281
$1\frac{1}{2}$	0.0937	$5\frac{1}{2}$	0.3437	$9\frac{1}{2}$	0.5937	$13\frac{1}{2}$	0.8437
$1\frac{3}{4}$	0.1094	$5\frac{3}{4}$	0.3593	$9\frac{3}{4}$	0.6093	$13\frac{3}{4}$	0.8593
2	0.1250	6	0.3750	10	0.6250	14	0.8750
$2\frac{1}{4}$	0.1406	$6\frac{1}{4}$	0.3906	$10\frac{1}{4}$	0.6406	$14\frac{1}{4}$	0.8906
$2\frac{1}{2}$	0.1562	$6\frac{1}{2}$	0.4062	$10\frac{1}{2}$	0.6562	$14\frac{1}{2}$	0.9062
$2\frac{3}{4}$	0.1718	$6\frac{3}{4}$	0.4218	$10\frac{3}{4}$	0.6718	$14\frac{3}{4}$	0.9218
3	0.1875	7	0.4375	11	0.6875	15	0.9375
$3\frac{1}{4}$	0.2031	$7\frac{1}{4}$	0.4531	$11\frac{1}{4}$	0.7031	$15\frac{1}{4}$	0.9531
$3\frac{1}{2}$	0.2187	$7\frac{1}{2}$	0.4687	$11\frac{1}{2}$	0.7187	$15\frac{1}{2}$	0.9687
$3\frac{3}{4}$	0.2343	$7\frac{3}{4}$	0.4843	$11\frac{3}{4}$	0.7343	$15\frac{3}{4}$	0.9843
4	0.2500	8	0.5000	12	0.7500	16	1.0000

Example illustrating the use of Tables I and II in converting kilograms to pounds and ounces avoirdupois:

What is the weight in pounds and ounces of a bale weighing 98.09 kgs.?

From Table II

98	kgs. =	216.0530 lbs.
.09	" = 9/100 of 2.2046	.1984 "
98.09 kgs. =		216.2514 lbs.

Table I shows that the decimal 0.2514 is nearly equivalent to 4 ozs.
 $\therefore$ 98.09 kgs. = 216 lbs. 4 ozs.—*Ans.*

METRIC SYSTEM

The metric system is compulsory in Austria, Belgium, France, Germany, Greece, Italy, Luxemburg, the Netherlands, Portugal, Roumania, Spain, Switzerland, Turkey, and most of the South American Republics; optional in Great Britain, the United States, and Russia.

FUNDAMENTAL EQUIVALENTS

The fundamental unit of the metric system is the **METER**—the unit of length. From this the units of capacity (**LITER**) and of weight (**GRAM**) were derived. All other units are the decimal subdivisions or multiples of these. These three units are simply related, e.g., for all practical purposes one **CUBIC DECIMETER** equals one **LITER** and one **LITER** of water weighs one **KILOGRAM**. The metric tables are formed by combining the words "**METER**," "**GRAM**," and "**LITER**" with the six numerical prefixes, as in the following tables:

Prefixes	Meaning		Units
milli-	= one thousandth	$\frac{1}{1000}$	.001
centi-	= one hundredth	$\frac{1}{100}$	.01
deci-	= one tenth	$\frac{1}{10}$	.1
<i>Unit</i>	= one		1
deka-	= ten	$\frac{10}{1}$	10
hecto-	= one hundred	$\frac{100}{1}$	100
kilo-	= one thousand	$\frac{1000}{1}$	1000
			" meter " for length
			" gram " for weight or mass.
			" liter " for capacity

All lengths, areas, and cubic measures in the following tables are derived from the International meter, the legal equivalent being 1 meter = 39.37 inches (law of July 28, 1866). In 1893 the United States Office of Standard Weights and Measures was authorized to derive the yard from the meter, using for the purpose the relation legalized in 1866, 1 yard

equals 3600/3937 meter. The customary weights are likewise referred to the kilogram (Executive order approved April 5, 1893). This action fixed the values, inasmuch as the reference standards are as perfect and unalterable as it is possible for human skill to make them.

All capacities are based on the practical equivalent 1 cubic decimeter equals 1 liter. The decimeter is equal to 3.937 inches in accordance with the legal equivalent of the meter given above. The gallon referred to in the tables is the United States gallon of 231 cubic inches. The bushel is the United States bushel of 2150.42 cubic inches. These units must not be confused with the British units of the same name which differ from those used in the United States. The British gallon is approximately 20 per cent larger and the British bushel 3 per cent larger than the corresponding units used in this country.

The customary weights derived from the International kilogram are based on the value 1 avoirdupois pound = 453.5924277 grams. This value is carried out further than that given in the law, but is in accord with the latter as far as it is there given. The value of the troy pound is based upon the relation just mentioned and also the equivalent 5760/7000 avoirdupois pound equals 1 troy pound.

METRIC EQUIVALENTS

LINEAR MEASURE

1 centimeter = 0.3937 in.	1 inch = 2.54 centimeters
1 decimeter = 3.937 in. = 0.328 ft.	1 foot = 3.048 decimeters
1 meter = 39.37 in. = 1.0936 yds.	1 yard = 0.9144 meter
1 decameter = 1.9884 rods	1 rod = 0.5029 decameter
1 kilometer = 0.62137 mile	1 mile = 1.6093 kilometers

(The meter, as used in Europe, is 39.370432 inches)

SQUARE MEASURE

1 sq. centimeter = 0.1550 sq. inch	1 sq. inch = 6.452 sq. centimeters
1 sq. decimeter = 0.1076 sq. foot	1 sq. foot = 9.2903 sq. decimeters
1 sq. meter = 1.196 sq. yards	1 sq. yard = 0.8361 sq. meter
1 are = 3.954 sq. rods	1 sq. rod = 0.2529 are
1 hectare = 2.47 acres	1 acre = 0.4047 hectare
1 sq. kilometer = 0.386 sq. mile	1 sq. mile = 0.259 sq. kilometer

WEIGHTS

1 decigram = 0.003527 oz. = 1.5432 grains

1 gram = 0.03527 oz. avoird., or about $15\frac{1}{2}$ troy grains.

1 kilogram = 2.2046 lbs. avoird.

1 metric ton = 1.1023 English short tons

1 ounce avoird. = 28.35 grams

1 pound avoird. = 0.4536 kilogram

1 English short ton = 0.9072 metric ton

APPROXIMATE METRIC EQUIVALENTS

1 decimeter = 4 inches

1 meter = 1.1 yards

1 kilometer = $\frac{5}{8}$ of a mile

1 hectare = $2\frac{1}{2}$ acres

1 stere, or cu. meter = $\frac{1}{4}$ of a cord

1 liter = 1.06 qt. liquid, 0.9 qt. dry

1 hectoliter = $2\frac{5}{8}$ bushels

1 kilogram = $2\frac{1}{6}$ lbs.

1 metric ton = 2200 lbs.

TABLE 102. COMPARISON OF AVOIRDUPOIS AND METRIC WEIGHTS

Grains	Drams	Oz. Av.	Lbs. Av.	Deniers	Grams
1.000	.....	.....	.....	1.296	0.065
27.340	1.000	.....	.....	35.437	1.772
437.500	16.000	1.000	.....	566.990	28.350
7000.000	256.000	16.000	1.000	9071.840	453.592
0.772	.....	.....	.....	1.000	0.050
15.432	.....	0.03527	.....	20.000	1.000

TABLE 103. EQUIVALENTS OF KILOGRAMS IN POUNDS TO FOUR DECIMAL PLACES

Kilos	Pounds	Kilos	Pounds	Kilos	Pounds	Kilos	Pounds
1	2.2046	32	70.5479	63	138.8912	94	207.2345
2	4.4092	33	72.7525	64	141.0958	95	209.4391
3	6.6139	34	74.9572	65	143.3005	96	211.6437
4	8.8185	35	77.1618	66	145.5051	97	213.8484
5	11.0231	36	79.3664	67	147.7097	98	216.0530
6	13.2277	37	81.5710	68	149.9143	99	218.2576
7	15.4324	38	83.7756	69	152.1189	100	220.4622
8	17.6370	39	85.9803	70	154.3236	101	222.6669
9	19.8416	40	88.1849	71	156.5282	102	224.8715
10	22.0462	41	90.3895	72	158.7328	103	227.0761
11	24.2508	42	92.5941	73	160.9374	104	229.2807
12	26.4555	43	94.7988	74	163.1421	105	231.4853
13	28.6601	44	97.0034	75	165.3467	106	233.6900
14	30.8647	45	99.2080	76	167.5513	107	235.8946
15	33.0693	46	101.4126	77	169.7559	108	238.0992
16	35.2740	47	103.6172	78	171.9605	109	240.3038
17	37.4786	48	105.8219	79	174.1652	110	242.5085
18	39.6832	49	108.0265	80	176.3698	111	244.7131
19	41.8878	50	110.2311	81	178.5744	112	246.9177
20	44.0924	51	112.4357	82	180.7790	113	249.1223
21	46.2971	52	114.6404	83	182.9837	114	251.3269
22	48.5017	53	116.8450	84	185.1883	115	253.5316
23	50.7063	54	119.0496	85	187.3929	116	255.7362
24	52.9109	55	121.2542	86	189.5975	117	257.9408
25	55.1156	56	123.4589	87	191.8021	118	260.1454
26	57.3202	57	125.6635	88	194.0068	119	262.3501
27	59.5248	58	127.8681	89	196.2011	120	264.5547
28	61.7294	59	130.0727	90	198.4160	200	440.9245
29	63.9340	60	132.2773	91	200.6206	300	661.3867
30	66.1387	61	134.4820	92	202.8253	400	881.8489
31	68.3433	62	136.6866	93	205.0299	500	1102.3112

TABLE 104. EQUIVALENTS OF POUND WEIGHTS IN KILOS AND DECIMALS

Lbs.	Kgs.	Lbs.	Kgs.	Lbs.	Kgs.	Lbs.	Kgs.
1	0.4536	28	12.7008	54	24.4944	80	36.2880
2	0.9072	29	13.1544	55	24.9480	81	36.7416
3	1.3608	30	13.6080	56	25.4016	82	37.1952
4	1.8144	31	14.0616	57	25.8552	83	37.6488
5	2.2680	32	14.5152	58	26.3088	84	38.1024
6	2.7216	33	14.9688	59	26.7624	85	38.5560
7	3.1752	34	15.4224	60	27.2160	86	39.0096
8	3.6288	35	15.8760	61	27.6696	87	39.4632
9	4.0824	36	16.3296	62	28.1232	88	39.9168
10	4.5360	37	16.7832	63	28.5768	89	40.3704
11	4.9896	38	17.2368	64	29.0304	90	40.8240
12	5.4432	39	17.6904	65	29.4840	91	41.2776
13	5.8968	40	18.1440	66	29.9376	92	41.7312
14	6.3504	41	18.5976	67	30.3912	93	42.1848
15	6.8040	42	19.0512	68	30.8448	94	42.6384
16	7.2576	43	19.5048	69	31.2984	95	43.0920
17	7.7112	44	19.9584	70	31.7520	96	43.5456
18	8.1648	45	20.4120	71	32.2056	97	43.9992
19	8.6184	46	20.8656	72	32.6592	98	44.4528
20	9.0720	47	21.3192	73	33.1128	99	44.9064
21	9.5256	48	21.7728	74	33.5664	100	45.3600
22	9.9792	49	22.2264	75	34.0200	150	68.0400
23	10.4328	50	22.6800	76	34.4736	200	90.7200
24	10.8864	51	23.1336	77	34.9272	300	136.0800
25	11.3400	52	23.5872	78	35.3808	400	181.4400
26	11.7936	53	24.0408	79	35.8344	500	226.8000
27	12.2472						

TABLE 105. EQUIVALENTS OF METRIC WEIGHTS IN POUNDS, OUNCES, AND GRAINS, AVOIRDUPOIS

Kilos	Lbs. Ozs. Grs.	Kilos	Lbs. Ozs. Grs.	Kilos	Lbs. Ozs. Grs.
1	2—3—119	39	85—15—293	77	169—12—29
2	4—6—239	40	88—2—413.0	78	171—15—149
3	6—9—359	41	90—6—95.2	79	174—2—268
4	8—13—41	42	92—9—214.9	80	176—5—388
5	11—0—161	43	94—12—334.6	81	178—9—70
6	13—3—280	44	97—0—16.8	82	180—12—190
7	15—6—400	45	99—3—136.5	83	182—15—310
8	17—10—82	46	101—6—256.2	84	185—2—429
9	19—13—202	47	103—9—375.9	85	187—6—112
10	22—0—322	48	105—13—58.1	86	189—9—231
11	24—4—4	49	108—0—177.8	87	191—12—351
12	26—7—123	50	110—3—297.5	88	194—0—33
13	28—10—243	51	112—6—417.2	89	196—3—153
14	30—13—363	52	114—10—99.4	90	198—6—273
15	33—1—45	53	116—13—219.1	91	200—9—392
16	35—4—165	54	119—0—338.8	92	202—13—74
17	37—7—284	55	121—4—21.0	93	205—0—194
18	39—10—404	56	123—7—140.7	94	207—3—314
19	41—14—87	57	125—10—260.4	95	209—6—434
20	44—1—207	58	127—13—380.1	96	211—10—116
21	46—4—326	59	130—1—62.3	97	213—13—235
22	48—8—8	60	132—4—182.0	98	216—0—355
23	50—11—128	61	134—7—301.7	99	218—4—37
24	52—14—247	62	136—10—421.4	100	220—7—157
25	55—1—367	63	138—14—103.6	101	222—10—276
26	57—5—49	64	141—1—223.3	102	224—13—396
27	59—8—169	65	143—4—343.0	103	227—1—79
28	61—11—289	66	145—8—25.2	104	229—4—198
29	63—14—408	67	147—11—144.9	105	231—7—318
30	66—2—91	68	149—14—264.6	106	233—11—0
31	68—5—210	69	152—1—384.3	107	235—14—20
32	70—8—330	70	154—5—66.5	108	238—1—239
33	72—12—12	71	156—8—186.2	109	240—4—359
34	74—15—132	72	158—11—305.9	110	242—8—42
35	77—2—252	73	160—14—425.6	200	440—14—314
36	79—5—371	74	163—2—107.8	300	661—6—34
37	81—9—53	75	165—5—227.5	400	881—13—191
38	83—12—173	76	167—8—347	500	1102—4—349

TABLE 106. GIVING THE EQUIVALENT OF METRIC WEIGHTS BY MULTIPLES OF 10 GRAMS, IN POUNDS, OUNCES, AND GRAINS, AVOIRDUPOIS

Grams	Lbs. Ozs. Grs.	Grams	Lbs. Ozs. Grs.	Grams	Lbs. Ozs. Grs.
10	0—0—154.3	380	0—13—175.9	750	1—10—197.5
20	0—0—308.6	390	0—13—330.2	760	1—10—351.8
30	0—1—25.4	400	0—14—47.0	770	1—11—68.6
40	0—1—179.7	410	0—14—201.3	780	1—11—222.9
50	0—1—334.0	420	0—14—355.6	790	1—11—377.2
60	0—2—50.8	430	0—15—72.4	800	1—12—94.0
70	0—2—205.1	440	0—15—226.7	810	1—12—248.3
80	0—2—359.4	450	0—15—381.0	820	1—12—402.6
90	0—3—76.2	460	1—0—97.8	830	1—13—119.4
100	0—3—230.5	470	1—0—252.1	840	1—13—273.7
110	0—3—384.8	480	1—0—406.4	850	1—13—428.0
120	0—4—101.6	490	1—1—123.2	860	1—14—144.8
130	0—4—255.9	500	1—1—277.5	870	1—14—299.1
140	0—4—410.2	510	1—1—431.8	880	1—15—15.9
150	0—5—127.0	520	1—2—148.6	890	1—15—170.2
160	0—5—281.3	530	1—2—302.9	900	1—15—324.5
170	0—5—435.6	540	1—3—19.7	910	2—0—41.3
180	0—6—152.4	550	1—3—174.0	920	2—0—195.6
190	0—6—306.7	560	1—3—328.3	930	2—0—349.9
200	0—7—23.5	570	1—4—45.1	940	2—1—66.7
210	0—7—177.8	580	1—4—199.4	950	2—1—221.0
220	0—7—332.1	590	1—4—353.7	960	2—1—375.3
230	0—8—48.9	600	1—5—70.5	970	2—2—92.1
240	0—8—203.2	610	1—5—224.8	980	2—2—246.4
250	0—8—357.5	620	1—5—379.1	990	2—2—400.7
260	0—9—74.3	630	1—6—95.9	1000	2—3—119.7
270	0—9—228.6	640	1—6—250.2	1 lb. avoird. = 16 oz. or 7000 grains 1 oz. avoird. = 437.5 grains 1 kilo. = 2 lbs. 3 ozs. and 119.7 grains, or 15,432.2 grains 1 gram = 15.43 grains 1 kilo. = 1000 grains	
280	0—9—382.9	650	1—6—404.5		
290	0—10—99.7	660	1—7—121.3		
300	0—10—254.0	670	1—7—275.6		
310	0—10—408.3	680	1—7—429.9		
320	0—11—125.1	690	1—8—146.7		
330	0—11—279.4	700	1—8—301.0		
340	0—11—433.7	710	1—9—17.8		
350	0—12—150.5	720	1—9—172.1		
360	0—12—304.8	730	1—9—326.4		
370	0—13—21.6	740	1—10—43.2		

EXAMPLE.—To convert 65 kgs. 450 grams to pounds, ounces, and grains, see Tables IV and V, thus:

	Lbs.	Ozs.	Grs.
65 kgs. =	143	4	343
450 gms. =		15	381
	143	19	724
143 lbs. =	143	0	0
19 ozs. =	1	3	0
724 grs. =	0	1	286.5
∴ 65 kgs. 450 gms. =	144	4	286.5

TABLE 107. SOME JAPANESE WEIGHTS AND MEASURES WITH ENGLISH AND METRIC EQUIVALENTS

WEIGHTS ¹

JAPANESE	ENGLISH	METRIC
1 Momme	0.13228 ounce (Av.)	3.75 grams
160 Momme = 1 Kin	1.32277 pounds (Av.)	600.00 grams
1000 Momme = 1 Kwan	8.26733 pounds (Av.)	3.7500 kilograms
756 Kin	1000 pounds (Av.)	453.6 kilograms

SHIPPING TONNAGE MEASURE ²

1 Koku = 10 cubic Shaku	9.45 cubic feet	0.2675 cu. meter
1 Koku = 0.1 Ton (Japanese)	9.45 cubic feet	0.2676 cu. meter
1 Ton = 100 cubic Shaku ³	94.40 cubic feet	2.6759 cu. meters

LINEAR MEASURE

1. Statutory Measures or Kane-Shaku

1 Bu	0.11930 inch	3.0303 millimeters
10 Bu = 1 Sun	1.19303 inches	3.0303 centimeters
10 Sun = 1 Shaku	11.93029 inches	0.30303 meter
10 Shaku = 1 Jo	3.3140 yards (U. S.)	3.0303 meters

2. Cloth Measure or Kujira-Shaku ⁴

1 Bu	0.14913 inch	0.3788 centimeter
10 Bu = 1 Sun	1.4913 inches	3.7879 centimeters
10 Sun = 1 Shaku	14.91257 inches	0.37879 meter
1 Shaku = 1.25 Kane	14.91312 inches	0.37879 meter
Shaku		
10 Shaku = 1 Jo	4.1425 yards	3.7879 meters

3. Itinerary and Land Measures

3 Kane = Shaku = 1 Ken	5.965 feet	1.81818 meters
60 Ken = 1 Cho	119.305 yards	109.09091 meters
36 Cho = 1 Ri	2.44029 miles	3.92727 kilometers
1 Ri (Marine) or Knot	1.1528 miles	1.85526 kilometers

¹ This is the commercial value used in the Japanese Custom House.² Used only in cases of sailing vessels of Japanese type.³ Used generally in cases of steamships and sailing vessels of European type in Japan.⁴ Japanese law—Article IV. The use of KUJIRAJAKU which has been in habitual use to the present day, is permitted only for the measurement of cloth.

AGRICULTURAL OR SQUARE MEASURES

1 Bu or Tsubo	3.9540 sq. yds.	0.03306 are
30 Bu = 1 Se	118.611 sq. yds.	0.99174 are
10 Se = 1 Tan	1186.105 sq. yds.	9.91736 are
10 Tan = 1 Cho	2.45062 acres	99.17355 are
1 Sq. Ri	5.95526 sq. miles	15.4288 sq. kilo.

DRY MEASURES

1 Shaku	0.0328 pint	0.01804 liter
10 Shaku = 1 Go	0.3276 pint	0.18039 liter
10 Go = 1 Sho	1.6381 quarts	1.80391 liters
10 Sho = 1 To	2.0476 pecks	18.03907 liters
10 To = 1 Koku	5.1190 bushels	180.39068 liters

LIQUID MEASURES

JAPANESE	ENGLISH	METRIC
1 Shaku	0.1525 gill	0.01804 liter
10 Shaku = 1 Go	0.38125 pint	0.18039 liter
10 Go = 1 Sho	1.8624 quarts	1.80391 liters
10 Sho = 1 To	4.7656 gals. (U. S.)	18.03907 liters
10 To = 1 Koku	47.656 gals. (U. S.)	180.39068 liters

COINS

1 Rin	0.04985 cent
10 Rin = 1 Sen	0.4985 cent
100 Sen = 1 Yen	49.85 cents

TABLE 108. SOME CHINESE WEIGHTS AND MEASURES WITH ENGLISH AND METRIC EQUIVALENTS

WEIGHTS

CHINESE	ENGLISH	METRIC
1 Mace	58.333 grains	3.7799 grams
10 Mace = 1 Tael or Leang	1.3333 oz. (Av.)	37.7986 grams
16 Taels = 1 Chin or Catty	1.333 lbs. (Av.)	.60478 kilos
16 Taels = 1 Kin	1.333 lbs. (Av.)	.60446 kilos
(Hong Kong Wt.)		
30 Catties = 1 Behar	40 lbs. (Av.)	18.14370 kilos
100 Catties = 1 Picul	133.333 lbs. (Av.)	60.478 kilos
120 Catties = 1 Shih	160 lbs. (Av.)	72.57479 kilos

LINEAR MEASURES

1 T'Sun	1.41	inches	3.581	cms.
10 T'Sun = 1 Ch'ih	14.1	inches	35.81	cms
56 T'Sun = 1 Kung	78.96	inches	2.006	meters
5 Ch'ih = 1 Pu	70.5	inches	1.7907	meters
360 Pu = 1 Li	.40057	mile	.64464	kilometer
10 Li = 1 Tang Sun	4.0057	miles	6.4464	kilometers
25 Li = 1 Tu	100.142	miles	161.1585	kilometers

LIQUID MEASURES

1 Sheng	1.088	quarts (U. S.)	1.029	liters
10 Sheng = 1 Tou	2.72	gals (U. S.)	10.289	liters
5.5 Tou = 1 Hu	14.96	gals. (U. S.)	56.589	liters
5 Hu = 1 Tan	29.92	gals. (U. S.)	113.178	liters

DRY MEASURE

1 Picki	3.22	bushels (U. S.)
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FOREIGN WEIGHTS AND THEIR ENGLISH EQUIVALENTS

Austria-Hungary.....	1 pfund	=	1.2346 lb.
Belgium.....	1 livre	=	1.102 lb.
Egypt.....	1 cantar	=	99.045 lb.
Germany.....	1 pfund	=	500 grams
Russia.....	{ 1 pound	=	0.9028 lb.
	{ 1 pood (40 pounds)	=	36.113 lb.
Sweden.....	1 pound	=	0.9377 lb.
Switzerland.....	1 zollfund	=	500 grams

CONVERSION FACTORS

If it is desired to convert in the opposite manner to that indicated below, interchange the words "multiply" and "divide." Example—To convert inches to centimeters, divide by 0.3937, or multiply by 2.54.

LENGTH

To convert—

Centimeters to inches multiply by	0.3937, or divide by	2.54
Meters to inches	" " 39.37, " " "	0.0254
Meters to yards (U. S.)	" " 1.0936, " " "	0.9144
Kilometers to miles	" " 0.621, " " "	1.6093

AREA

Centimeters to sq. inches multiply by 0.155 or divide by 6.451
 Square meters to sq. feet " " 10.7664 " " " 0.0929

VOLUME

Cu. centimeters to cubic inches multiply by 16.383
 Cu. meters to cubic yards " " 1.358
 Liters to gallons (231 cu. in.) " " .2642 or divide by 3.78

WEIGHTS

Grams to grains, multiply by 15.432, or divide by 0.065
 Grams to drams, " " 0.5644, " " " 1.772
 Grams to deniers, " " 20 " " " 0.05
 Deniers to drams, " " 0.028, " " " 35.437
 Deniers to grams, " " 0.05 " " " 20
 Grams to ounces Av., multiply by 0.0353, or divide by 28.35
 Kilograms to ounces Av., multiply by 35.3, or divide by 0.02835
 Kilograms to pounds Av., " " 2.2, " " " 0.454

MISCELLANEOUS

Centigrade degrees to Fahrenheit, multiply by 1.8 and add 32
 Fahrenheit degrees to Centigrade, subtract 32 and divide by 1.8
 Calories to British Thermal Units, multiply by 3.968
 Cheval vapeur to horse-power " " 0.9863
 Watts to foot-pounds per second, " " 0.7373
 Watts to horse-power, divide by 746
 Kilowatts to horse-power, multiply by 1.34
 Kilograms per sq. cm. to lbs. per sq. in., multiply by 14.223
 Grams per cubic cm. to lbs. per cu. in., divide by 27.7
 Meters per second to feet per minute, multiply by 196.86

DEFINITIONS

The Small Calorie is the amount of heat required to raise the temperature of one gram of water one degree Centigrade.

The Large Calorie is the amount of heat required to raise the temperature of one kilogram of water one degree Centigrade. It is therefore one thousand times as large as the small calorie.

The British Thermal Unit (B. T. U.) is the heat required to raise the temperature of one pound of water one degree Fahrenheit.

The Heat of Combustion of a substance is the number of small or large calories of heat evolved during the combustion of a gram or a kilogram of

the substance. Using the English weights and measures it is the number of B. T. U. of heat evolved during the combustion of one pound of the substance.

The Ohm is the unit in which the resistance of a conductor to the passing of electric energy is expressed.

The Ampere is the unit in which the rate of transmission of electric energy is expressed.

The Volt is the unit of electromotive force or electrical pressure.

The Watt is the unit of power, the power of one ampere of current at an electrical pressure of one volt.

The Kilowatt equals 1000 watts, equivalent to approximately one and a third horsepower.

YARN NUMBERING

There are many systems by which the "number," "size," or "count" of yarns is expressed. While many of them are used only in particular districts or countries, each is based on one of two general principles, viz.: either the weight of a definite length or the length contained in a definite weight. The number, or count, is therefore expressed below, either as the weight of a standard unit skein or hank, or the number of standard skeins required to weigh a standard amount. Folded yarns, "numbered on the single yarn," are expressed with the ply first and then the single yarn number from which they are spun. Thus, 3/60 means, 60's single-folded to 20. Folded yarns, "numbered as found," are expressed with the number as found first and then the ply. Thus, 40/2 means that the 40 is doubled from 2 single 80's. For average and resultant counts for mixed yarns of the same or different denominations see some manual on textile calculations. (Example: Bradbury, "Calculations in Yarns and Fabrics," pp. 37 to 52, Ashenhurst, "Textile Calculations and Structure of Fabrics," pp. 19 to 32.)

ALL YARNS

INTERNATIONAL METRIC COUNT, for all kinds of yarn.

The yarn count is the number of meters in one gram.

No. 20 means a length of 20 meters weighs one gram (adopted by the Paris Conference of 1900).

SILK

RAW SILK

LEGAL DENIER COUNT. Adopted at Paris Conference 1900.

The size is the weight of a 450-meter skein in deniers (5 centigrams).

THROWN SILK

LEGAL DENIER COUNT. Same as for raw silk.

ENGLISH DRAM COUNT. Used principally in England and America.

The size is the weight of a 1000-yard skein in drams.

YORKSHIRE OUNCE SYSTEM. Used only in England.

The size is the number of yards in one ounce avoirdupois.

SPUN SILK

ENGLISH SYSTEM.

This is the same as the English Cotton System, except that the folded yarns are numbered as found instead of on the basis of the single.

CONTINENTAL SYSTEM.

The size is the number of 1000-meter skeins in one kilogram. Folded yarns are numbered on the single yarn.

SILK NOIL YARN

CUT SYSTEM.

The size is the number of "cuts" of 300 yards in one pound.

ARTIFICIAL SILK

LEGAL DENIER SYSTEM. The same as natural silk.

COTTON

ENGLISH COTTON COUNT.

The count is the number of 840-yard hanks in a pound avoirdupois.

Folded yarns are numbered on the single yarns from which they are spun.

CONTINENTAL SYSTEM. Same as International System.

The count is the number of 1000-meter hanks in one-half kilogram.

Folded yarns are numbered on the singles from which they are spun.

WORSTED

ENGLISH WORSTED COUNT.

The count is the number of 560-yard hanks in one pound. Folded yarns are numbered on the single yarn from which they are spun.

CONTINENTAL SYSTEM. Same as International System.

The count is the number of 1000-meter hanks in one kilogram. Folded yarns are numbered on the single yarn from which they are spun.

WOOLEN

YORKSHIRE COUNT.

The count is the number of 256-yard hanks in a pound, or the number of yards weighing one dram.

GALASHIELS COUNT.

The count is the number of 300-yard "cuts" or hanks in 24 ounces, or its equivalent, the number of 200-yard "cuts" or hanks in a pound.

WEST OF ENGLAND COUNT.

The count is the number of 320-yard hanks in a pound or the number of 20-yard hanks in an ounce.

AMERICAN SYSTEM.

Grain count. The count is the weight of 20-yard skein in grains run count (New England). The count is the number of 1600-yard hanks in a pound or the weight of 100-yard in ounces. Cut count (Philadelphia). The count is the number of 300-yard "cuts" or hanks in a pound.

LINEN AND HEMP**ENGLISH COUNT.**

The count is the number of 300-yard hanks or leas in a pound. Folded yarns are numbered on the single yarn from which they are spun. A spindle of linen is 14,400 yards. A bundle of linen is 200 leas, equal to 60,000 yards.

CONTINENTAL COUNT.

The count is the number of 1000-meter hanks in one-half kilogram,

JUTE AND HEAVY FLAXES AND HEMP**DUNDEE JUTE COUNT.**

The number is the weight of a spindle, 14,400 yards in a pound.

RAMIE**ENGLISH COUNT.**

The count is the number of 300-yard hanks in a pound.

CONTINENTAL COUNT. Same as International System.

The count is the number of 1000-meter hanks in one kilogram.

MOHAIR AND CAMELS' HAIR

Same as the systems for worsted.

YARN COUNT CONVERSION FACTORS

The *Textile Recorder*, August, 1902, contained a table computed by Watson, by which if the length is known in yards and the weight in grains, the count can be computed for any of the systems given.

TABLE 109. YARN COUNT CONVERSION FACTORS

Material	System	Weight in Grains of 1 Yard of 1's Yarn
All Yarns.....	Metric.....	14.11
Worsted.....	Continental.....	14.11
“.....	English, American.....	12.5
“.....	French (Roubaix).....	9.93
“.....	French (Fournies).....	4.97
Spun Silk.....	French, Swiss.....	14.11
“.....	English, German, American.....	8.33
Cotton.....	English, German, Swiss, American.....	8.33
“.....	French.....	7.05
Linen, Hemp.....	Almost Universal.....	23.33
Ramie.....	English.....	23.33
“.....	Continental.....	14.11
Woolen.....	Yorkshire Skeins.....	27.34
“.....	West of England.....	21.87
“.....	American Run.....	4.375
“.....	German.....	4.81
“.....	Belgian, French (Sedan).....	4.72
“.....	French (Elbeuf).....	1.96
Raw Silk.....	Ounce System.....	437.5

Rule for Table 108.—Divide the number of yards in the sample by its weight in grains and multiply the quotient by the factor given in the table.

TABLE 110. CONVERSION FACTORS

Material	System	Number of Yards of 1's Yarn which Weigh 1 Grain
Raw Silk.....	Dram System.....	365
“.....	Denier System.....	634
Woolen.....	American Grain.....	20

Rule for Table LIV. Divide the weight of the sample in grains by its length in yards and multiply the quotient by the factor given in the table.

To convert—

English worsted to metric worsted divide by 0.886

English cotton to metric cotton divide by 1.18

English spun silk to metric spun silk multiply by 1.694

Drams per 1000 yards to deniers per 450 meters multiply by 17.44

Deniers per 450 meters to drams per 1000 yards divide by 17.44

Cotton and spun silk to worsted multiply by 1.5

Cotton and spun silk to woolen, Yorkshire skein, multiply by 2.685

Cotton and spun silk to woolen, West England, multiply by 2.625

Cotton and spun silk to linen, wet spun, multiply by 2.8

TABLE III. COMPARATIVE YARN TABLES

Spun Silk and Cotton Scale	Yards per Pound	Yards per Ounce	Meters per Kilogram	Scale in Legal Deniers	Drams per 1000 Yds.	Linen Scale. Leas of 300 Yds. in 1 Lb.	Wor- sted Scale
1	840	52½	1,692	5314.915	304.761	2.800	1½
1½	1,260	78¾	2,539	3543.277	203.174	4.200	2¼
2	1,680	105	3,384	2657.457	152.380	5.600	3
2½	2,100	131¼	4,232	2125.966	121.904	7.000	3¾
3	2,520	157½	5,078	1771.638	101.587	8.400	4½
3½	2,940	183¾	5,925	1518.547	87.074	9.800	5¼
4	3,360	210	6,768	1328.729	76.190	11.200	6
4½	3,780	236¼	7,617	1181.092	67.195	12.600	6¾
5	4,200	262½	8,464	1062.983	60.952	14.000	7½
5½	4,620	288¾	9,310	966.349	55.411	15.400	8¼
6	5,040	315	10,157	885.819	50.793	16.800	9
6½	5,460	341¼	11,003	817.679	46.886	18.200	9¾
7	5,880	367½	11,850	759.274	43.537	19.600	10½
7½	6,300	393¾	12,696	708.655	40.634	21.000	11¼
8	6,720	420	13,536	664.364	38.095	22.400	12
8½	7,140	446¼	14,389	625.284	35.854	23.800	12¾
9	7,560	472½	15,235	590.546	33.597	25.200	13½
9½	7,980	498¾	16,082	559.465	32.080	26.600	14¼
10	8,400	525	16,928	531.491	30.476	28.000	15
10½	8,820	551¼	17,775	506.182	29.024	29.400	15¾
11	9,240	577½	18,621	483.172	27.705	30.800	16½
11½	9,660	603¾	19,468	462.166	26.501	32.200	17¼
12	10,080	630	20,314	442.910	25.396	33.600	18
12½	10,500	656¼	21,161	425.193	24.380	35.000	18¾
13	10,920	682½	22,007	408.839	23.443	36.400	19½
13½	11,340	708¾	22,853	393.698	22.574	37.800	20¼
14	11,760	735	23,700	379.637	21.768	39.200	21
14½	12,180	761¼	24,546	366.546	21.018	40.600	21¾
15	12,600	787½	25,393	354.328	20.317	42.000	22½
15½	13,020	813¾	26,239	342.898	19.662	43.400	23¼
16	13,440	840	27,072	332.182	19.047	44.800	24
16½	13,860	866¼	27,932	322.115	18.470	46.200	24¾

TABLE III. COMPARATIVE YARN TABLES—*Continued*

Spun Silk and Cotton Scale	Yards per Pound	Yards per Ounce	Meters per Kilogram	Scale in Legal Deniers	Drams per 1000 Yds.	Linen Scale. Leas of 300 Yds. in 1 Lb.	Wor- sted Scale
17	14,280	892½	28,779	312.642	17.927	47.600	25½
17½	14,700	918¾	29,625	303.709	17.414	49.000	26¼
18	15,120	945	30,471	295.273	16.798	50.400	27
18½	15,540	971¼	31,318	287.293	16.473	51.800	27¾
19	15,960	997½	32,164	279.732	16.040	53.200	28½
19½	16,380	1023¾	33,011	272.560	15.628	54.600	29¼
20	16,800	1050	33,857	265.746	15.238	56.000	30
20½	17,220	1076¼	34,704	259.264	14.866	57.400	30¾
21	17,640	1102½	35,550	253.091	14.512	58.800	31½
21½	18,060	1128¾	36,397	247.205	14.174	60.200	32¼
22	18,480	1155	37,243	241.586	13.852	61.600	33
22½	18,900	1181¼	38,089	236.218	13.544	63.000	33¾
23	19,320	1207½	38,936	231.083	13.250	64.400	34½
23½	19,740	1233¾	39,782	226.167	12.968	65.800	35¼
24	20,160	1260	40,629	221.455	12.698	67.200	36
24½	20,580	1286¼	41,475	216.936	12.439	68.600	36¾
25	21,000	1312½	42,322	212.597	12.190	70.000	37½
25½	21,420	1338¾	43,168	208.428	11.951	71.400	38¼
26	21,840	1365	44,015	204.420	11.721	72.800	39
26½	22,260	1391¼	44,861	200.563	11.500	74.200	39¾
27	22,680	1417½	45,707	196.849	11.287	75.600	40½
27½	23,100	1443¾	46,554	193.270	11.082	77.000	41¼
28	23,520	1470	47,400	189.818	10.884	78.400	42
28½	23,940	1496¼	48,247	186.488	10.693	79.800	42¾
29	24,360	1522½	49,093	183.273	10.509	81.200	43½
29½	24,780	1548¾	49,940	180.167	10.330	82.600	44¼
30	25,200	1575	50,786	177.164	10.158	84.000	45
30½	25,620	1601¼	51,632	174.260	9.992	85.400	45¾
31	26,040	1627½	52,479	171.449	9.831	86.800	46½
31½	26,460	1653¾	53,325	168.727	9.674	88.200	47¼
32	26,880	1680	54,144	166.091	9.523	89.600	48
32½	27,300	1706¼	55,018	163.536	9.377	91.000	48¾

TABLE III. COMPARATIVE YARN TABLES—*Continued*

Spun Silk and Cotton Scale	Yards per Pound	Yards per Ounce	Meters per Kilogram	Scale in Legal Deniers	Drams per 1000 Yds.	Linen Scale. Leas of 300 Yds. in 1 Lb.	Wor- sted Scale
33	27,720	1732½	55,865	161.057	9.235	92.400	49½
33½	28,140	1758¾	56,711	158.654	9.097	93.800	50¼
34	28,560	1785	57,558	156.321	8.963	95.200	51
34½	28,980	1811¼	58,404	154.055	9.833	96.600	51¾
35	29,400	1837½	59,250	151.855	8.707	98.000	52½
35½	29,820	1863¾	60,097	149.716	8.584	99.400	53¼
36	30,240	1890	60,943	147.637	8.399	100.800	54
36½	30,660	1916¼	61,790	145.614	8.349	102.200	54¾
37	31,080	1942½	62,636	143.646	8.236	103.600	55½
37½	31,500	1968¾	63,483	141.731	8.126	105.000	56¼
38	31,920	1995	64,329	139.866	8.020	106.400	57
38½	32,340	2021¼	65,176	138.049	7.915	107.800	57¾
39	32,760	2047½	66,022	136.280	7.814	109.200	58½
39½	33,180	2073¾	66,868	134.555	7.715	110.600	59¼
40	33,600	2100	67,715	132.873	7.619	112.000	60
40½	34,020	2126¼	68,561	131.233	7.524	113.400	60¾
41	34,440	2152½	69,408	129.632	7.433	114.800	61½
41½	34,860	2178¾	70,254	128.070	7.343	116.200	62¼
42	35,280	2205	71,101	126.546	7.256	117.600	63
42½	35,700	2231¼	71,947	125.057	7.170	119.000	63¾
43	36,120	2257½	72,794	123.603	7.087	120.400	64½
43½	36,540	2283¾	73,640	122.182	7.006	121.800	65¼
44	36,960	2310	74,486	120.793	6.926	123.200	66
44½	37,380	2336¼	75,333	119.436	6.848	124.600	66¾
45	37,800	2362½	76,179	118.109	6.772	126.000	67½
45½	38,220	2388¾	77,026	116.811	6.698	127.400	68¼
46	38,640	2415	77,872	115.542	6.625	128.800	69
46½	39,060	2441¼	78,719	114.289	6.554	130.200	69¾
47	39,480	2467½	79,565	113.083	6.484	131.600	70½
47½	39,900	2493¾	80,412	111.893	6.416	133.000	71¼
48	40,320	2520	81,258	110.727	6.349	134.400	72
48½	40,740	2546¼	82,104	109.586	6.283	135.800	72¾

TABLE III. COMPARATIVE YARN TABLES—*Continued*

Spun Silk and Cotton Scale	Yards per Pound	Yards per Ounce	Meters per Kilogram	Scale in Legal Deniers	Drams per 1000 Yds.	Linen Scale. Leas of 300 Yds. in 1 Lb.	Wor- sted Scale
49	41,160	2572½	82,951	108.468	6.219	137.200	73½
49½	41,580	2598¾	83,797	107.149	6.156	138.600	74¼
50	42,000	2625	84,644	106.298	6.095	140.000	75
51	42,840	2677½	86,337	104.214	5.975	142.800	76½
52	43,680	2730	88,030	102.210	5.860	145.600	78
53	44,520	2782½	89,722	100.281	5.750	148.400	79½
54	45,360	2835	91,415	98.425	5.643	151.200	81
55	46,200	2887½	93,108	96.635	5.541	154.000	82½
56	47,040	2940	94,801	94.909	5.442	156.800	84
57	47,880	2992½	96,494	93.244	5.346	159.600	85½
58	48,720	3045	98,195	91.637	5.254	162.400	87
59	49,560	3097½	99,880	90.083	5.165	165.200	88½
60	50,400	3150	101,573	88.582	5.079	168.000	90
61	51,240	3202½	103,265	87.130	4.996	170.800	91½
62	52,080	3255	104,958	85.725	4.915	173.600	93
63	52,920	3307½	106,651	84.364	4.837	176.400	94½
64	53,760	3360	108,288	83.045	4.761	179.200	96
65	54,600	3412½	110,037	81.768	4.688	182.000	97½
66	55,440	3465	111,730	80.529	4.617	184.800	99
67	56,280	3517½	113,423	79.327	4.548	187.600	100½
68	57,120	3570	115,116	78.161	4.481	190.400	102
69	57,960	3622½	116,809	77.028	4.416	193.200	103½
70	58,800	3675	118,501	75.927	4.353	196.000	105
71	59,640	3737½	120,194	74.858	4.292	198.800	106½
72	60,480	3780	121,887	73.818	4.199	201.600	108
73	61,320	3832½	123,580	72.807	4.174	204.400	109½
74	62,160	3885	125,273	71.823	4.118	207.200	111
75	63,000	3937½	126,966	70.866	4.063	210.000	112½
76	63,840	3990	128,659	69.933	4.010	212.800	114
77	64,680	4042½	130,352	69.025	3.957	215.600	115½
78	65,520	4095	132,045	68.140	3.907	218.400	117
79	66,360	4147½	133,737	67.277	3.857	221.200	118½

TABLE III. COMPARATIVE YARN TABLES—*Continued*

Spun Silk and Cotton Scale	Yards per Pound	Yards per Ounce	Meters per Kilogram	Scale in Legal Deniers	Drams per 1000 Yds.	Linen Scale. Leas of 300 Yds. in 1 Lb.	Wor- sted Scale
80	67,200	4200	135,430	66.436	3.809	224.000	120
81	68,040	4252½	137,123	65.616	3.762	226.800	121½
82	68,880	4305	138,816	64.816	3.716	229.600	123
83	69,720	4357½	140,509	64.035	3.671	232.400	124½
84	70,560	4410	142,202	63.273	3.628	235.200	126
85	71,400	4462½	143,895	62.528	3.585	238.000	127½
86	72,240	4515	145,588	61.801	3.543	240.800	129
87	73,080	4567½	147,280	61.091	3.503	243.600	130½
88	73,920	4620	148,973	60.396	3.463	246.400	132
89	74,760	4672½	150,666	59.718	3.424	249.200	133½
90	75,600	4725	152,359	59.055	3.386	252.000	135
91	76,440	4777½	154,052	58.406	3.349	254.800	136½
92	77,280	4830	155,744	57.771	3.312	257.600	138
93	78,120	4882½	157,438	57.150	3.277	260.400	139½
94	78,960	4935	159,131	56.542	3.242	263.200	141
95	79,800	4987½	160,824	55.946	3.208	266.000	142½
96	80,640	5040	162,516	55.364	3.174	268.800	144
97	81,480	5092½	164,209	54.793	3.141	271.600	145½
98	82,320	5145	165,902	54.234	3.109	274.400	147
99	83,160	5197½	167,595	53.575	3.078	277.200	148½
100	84,000	5250	169,288	53.149	3.047	280.000	150

TABLE III. COMPARATIVE YARN TABLES—*Continued*

Spun Silk and Cotton Scale	Yards per Pound	Yards per Ounce	Meters per Kilogram	Scale in Legal Deniers	Drams per 1000 Yds.	Linen Scale Leas of 300 Yds. in 1 Lb.
105	88,200	5,512½	177,752	50.618	2.902	294.000
110	92,400	5,775	186,217	48.317	2.770	308.000
115	96,600	6,037½	194,681	46.217	2.650	322.000
120	100,800	6,300	203,146	44.291	2.539	336.000
125	105,000	6,562½	211,610	42.519	2.438	350.000
130	109,200	6,825	220,075	40.884	2.344	364.000
135	113,400	7,087½	228,539	39.370	2.257	378.000
140	117,600	7,350	237,003	37.964	2.176	392.000
145	121,800	7,612½	245,468	36.655	2.101	406.000
150	126,000	7,875	253,932	35.433	2.031	420.000
155	130,200	8,137½	262,397	34.290	1.966	434.000
160	134,400	8,400	270,861	33.218	1.904	448.000
165	138,600	8,662½	279,326	32.211	1.847	462.000
170	142,800	8,925	287,790	31.264	1.792	476.000
175	147,000	9,187½	296,254	30.371	1.741	490.000
180	151,200	9,450	304,719	29.527	1.693	504.000
185	155,400	9,712½	313,183	28.729	1.647	518.000
190	159,600	9,975	321,648	27.973	1.604	532.000
195	163,800	10,237½	330,112	27.256	1.562	546.000
200	168,000	10,500	338,577	26.575	1.523	560.000
205	172,200	10,762½	347,041	25.926	1.486	574.000
210	176,400	11,025	355,505	25.309	1.451	588.000
215	180,600	11,287½	363,970	24.721	1.417	602.000
220	184,800	11,550	372,432	24.159	1.385	616.000
225	189,000	11,812½	380,898	23.622	1.354	630.000
230	193,200	12,075	389,363	23.108	1.325	644.000
235	197,400	12,337½	397,827	22.617	1.296	658.000
240	201,600	12,600	406,292	22.146	1.269	672.000
245	205,800	12,862½	414,756	21.694	1.243	686.000
250	210,000	13,125	423,221	21.260	1.219	700.000
255	214,200	13,387½	431,685	20.843	1.195	714.000
260	218,400	13,650	440,150	20.442	1.172	728.000
265	222,600	13,912½	448,614	20.056	1.150	742.000

TABLE III. COMPARATIVE YARN TABLES—*Continued*

Spun Silk and Cotton Scale	Yards per Pound	Yards per Ounce	Meters per Kilogram	Scale in Legal Deniers	Drams per 1000 Yds.	Lineñ Scale. Leas of 300 Yds. in 1 Lb.
270	226,800	14,175	457,078	19.685	1.128	756.000
275	231,000	14,437½	465,543	19.327	1.108	770.000
280	235,200	14,700	474,007	18.982	1.088	784.000
285	239,400	14,962½	482,472	18.649	1.069	798.000
290	243,600	15,225	490,936	18.327	1.050	812.000
295	247,800	15,487½	499,401	18.017	1.033	826.000
300	252,000	15,750	507,865	17.716	1.015	840.000
305	256,200	16,012½	516,329	17.426	0.999	854.000
310	260,400	16,275	524,794	17.145	0.983	868.000
315	264,600	16,537½	533,258	16.873	0.967	882.000
320	268,800	16,800	541,723	16.609	0.952	896.000
325	273,000	17,062½	550,187	16.354	0.937	910.000
330	277,200	17,325	558,652	16.106	0.923	924.000
335	281,400	17,587½	567,116	15.865	0.909	928.000
340	285,600	17,850	575,580	15.632	0.896	952.000
345	289,800	18,112½	584,045	15.406	0.883	966.000
350	294,000	18,375	592,509	15.186	0.870	980.000
355	298,200	18,637½	600,974	14.972	0.858	994.000
360	302,400	18,900	609,438	14.764	0.846	1008.000
365	306,600	19,162½	617,903	14.561	0.834	1022.000
370	310,800	19,425	626,367	14.365	0.823	1036.000
375	315,000	19,687½	634,832	14.173	0.812	1050.000
380	319,200	18,950	643,296	13.987	0.802	1064.000
385	323,400	20,212½	651,761	13.805	0.791	1078.000
390	327,600	20,475	660,225	13.628	0.781	1092.000
395	331,800	20,737½	668,690	13.455	0.771	1106.000
400	336,000	21,000	677,155	13.287	0.761	1120.000
405	340,200	21,262½	685,619	13.123	0.752	1134.000
410	344,400	21,525	694,082	12.963	0.743	1148.000
415	348,600	21,787½	702,548	12.807	0.734	1162.000
420	352,800	22,050	711,011	12.655	0.725	1176.000
425	357,000	22,312½	719,477	12.506	0.717	1190.000
430	361,200	22,575	727,940	12.360	0.708	1204.000

TABLE III. COMPARATIVE YARN TABLES—*Continued*

Spun Silk and Cotton Scale	Yards per Pound	Yards per Ounce	Meters per Kilogram	Scale in Legal Deniers	Drams per 1000 Yds.	Linen Scale. Leas of 300 Yds. in 1 Lb.
435	365,400	22,837½	736,406	12.218	0.700	1218.000
440	369,600	23,100	744,869	12.079	0.692	1232.000
445	373,800	23,362½	753,334	11.944	0.684	1246.000
450	378,000	23,625	761,797	11.811	0.677	1260.000
455	382,200	23,887½	770,262	11.681	0.669	1274.000
460	386,400	24,150	778,727	11.554	0.662	1288.000
465	390,600	24,412½	787,191	11.429	0.655	1302.000
470	394,800	24,675	795,655	11.308	0.648	1316.000
475	399,000	24,937½	804,120	11.189	0.641	1330.000
480	403,200	25,200	812,584	11.073	0.634	1344.000
485	407,400	25,462½	821,048	10.959	0.628	1358.000
490	411,600	25,725	829,513	10.847	0.621	1372.000
495	415,800	25,987½	837,977	10.715	0.615	1386.000
500	420,000	26,250	846,443	10.630	0.609	1400.000
505	424,200	26,512½	854,906	10.525	0.603	1414.000
510	428,400	26,775	863,371	10.421	0.597	1428.000
515	432,600	27,037½	871,835	10.320	0.591	1442.000
520	436,800	27,300	880,300	10.221	0.586	1456.000
525	441,000	27,562½	888,764	10.124	0.580	1470.000
530	445,200	27,825	897,229	10.028	0.575	1484.000
535	449,400	28,087½	905,692	9.934	0.569	1498.000
540	453,600	28,350	914,157	9.843	0.564	1512.000
545	457,800	28,612½	922,621	9.752	0.559	1526.000
550	462,000	28,875	931,086	9.664	0.554	1540.000
555	466,200	29,137½	939,550	9.576	0.549	1554.000
560	470,400	29,400	948,015	9.491	0.544	1568.000
565	474,600	29,662½	956,479	9.407	0.539	1582.000
570	478,800	29,925	964,944	9.324	0.534	1596.000
575	483,000	30,187½	973,409	9.244	0.530	1610.000
580	487,200	30,450	981,873	9.164	0.525	1624.000
585	491,400	30,712½	990,338	9.085	0.520	1638.000
590	495,600	30,975	998,802	9.008	0.516	1652.000
595	499,800	31,237½	1,007,267	8.933	0.512	1666.000
600	504,000	31,500	1,015,731	8.858	0.507	1680.000

TABLE 112. NUMBERING COTTON YARN AND SPUN SILK BY WEIGHT IN GRAINS OF 120 YARDS

No. of Yarn	120 yards Weight in Grains	No. of Yarn	120 yards Weight in Grains	No. of Yarn	120 yards Weight in Grains	No. of Yarn	120 yards Weight in Grains
1	1000.00	51	19.61	101	9.90	151	6.62
2	500.00	52	19.23	102	9.80	152	6.58
3	333.33	53	18.87	103	9.71	153	6.54
4	250.00	54	18.52	104	9.62	154	6.49
5	200.00	55	18.18	105	9.52	155	6.45
6	166.67	56	17.86	106	9.43	156	6.41
7	142.86	57	17.55	107	9.35	157	6.37
8	125.00	58	17.24	108	9.26	158	6.33
9	111.11	59	16.95	109	9.17	159	6.29
10	100.00	60	16.67	110	9.09	160	6.25
11	90.91	61	16.39	111	9.01	161	6.21
12	83.33	62	16.13	112	8.93	162	6.17
13	76.92	63	15.87	113	8.85	163	6.13
14	71.43	64	15.62	114	8.77	164	6.10
15	66.67	65	15.38	115	8.70	165	6.06
16	62.50	66	15.15	116	8.62	166	6.02
17	58.82	67	14.93	117	8.55	167	5.99
18	55.56	68	14.71	118	8.47	168	5.95
19	52.63	69	14.49	119	8.40	169	5.92
20	50.00	70	14.29	120	8.33	170	5.88
21	47.62	71	14.08	121	8.26	171	5.85
22	45.45	72	13.89	122	8.20	172	5.81
23	43.48	73	13.70	123	8.13	173	5.78
24	41.67	74	13.51	124	8.06	174	5.75
25	40.00	75	13.33	125	8.00	175	5.71
26	38.46	76	13.16	126	7.94	176	5.68
27	37.04	77	12.99	127	7.87	177	5.65
28	35.71	78	12.82	128	7.81	178	5.62
29	34.48	79	12.66	129	7.75	179	5.59
30	33.33	80	12.50	130	7.69	180	5.56
31	32.26	81	12.35	131	7.63	181	5.52
32	31.25	82	12.20	132	7.58	182	5.49
33	30.30	83	12.05	133	7.52	183	5.46
34	29.41	84	11.90	134	7.46	184	5.43
35	28.57	85	11.76	135	7.41	185	5.41
36	27.78	86	11.63	136	7.35	186	5.38
37	27.03	87	11.49	137	7.30	187	5.35
38	26.32	88	11.36	138	7.25	188	5.32
39	25.64	89	11.24	139	7.19	189	5.29
40	25.00	90	11.11	140	7.14	190	5.26
41	24.39	91	10.99	141	7.09	191	5.24
42	23.81	92	10.87	142	7.04	192	5.21
43	23.26	93	10.75	143	6.99	193	5.18
44	22.73	94	10.64	144	6.94	194	5.15
45	22.22	95	10.53	145	6.90	195	5.13
46	21.74	96	10.42	146	6.85	196	5.10
47	21.28	97	10.31	147	6.80	197	5.08
48	20.83	98	10.20	148	6.76	198	5.05
49	20.41	99	10.10	149	6.71	199	5.03
50	20.00	100	10.00	150	6.67	200	5.00

TABLE 113. YARDS OF SILK TO THE POUND IN SIZES 9/11 TO 16/18 DENIERS, TAKING THE AVERAGE OF THE SIZE

Explanation: 1. The table gives the raw silk yards to the pound.

2. If thrown unsoaked, the silk is shortened about three per cent, depending on the varying twists and threads.

3. The difference between the raw and thrown silk boil-off, when added to this three per cent, indicates the number of the table to be used up to ten.

RAW	(3) Thrown 3% Shortening	(4) 3% Shortening + 1% Soap	(5) 3% Shortening + 2% Soap	(6) 3% Shortening + 3% Soap	(7) 3% Shortening + 4% Soap	(8) 3% Shortening + 5% Soap	(9) 3% Shortening + 6% Soap	(10) 3% Shortening + 7% Soap
16/18-16 $\frac{1}{2}$ to 17 $\frac{1}{2}$	255,100 to 270,600	247,400 to 262,500	244,900 to 259,800	239,800 to 254,400	237,200 to 251,700	234,700 to 249,000	232,100 to 246,200	229,600 to 243,500
15/17-15 $\frac{1}{2}$ to 16 $\frac{1}{2}$	270,600 to 288,000	262,500 to 279,400	259,800 to 276,500	254,400 to 270,700	251,700 to 267,800	249,000 to 265,000	246,200 to 262,000	243,500 to 259,200
14/16-14 $\frac{1}{2}$ to 15 $\frac{1}{2}$	288,000 to 307,900	279,400 to 298,700	276,500 to 295,600	270,700 to 289,400	267,800 to 286,300	265,000 to 283,300	262,000 to 280,200	259,200 to 277,100
13/15-13 $\frac{1}{2}$ to 14 $\frac{1}{2}$	307,900 to 330,700	298,700 to 320,800	295,600 to 317,500	289,400 to 310,900	286,300 to 307,600	283,300 to 304,200	280,200 to 300,900	277,100 to 297,600
12/14-12 $\frac{1}{2}$ to 13 $\frac{1}{2}$	330,700 to 357,100	320,800 to 346,400	317,500 to 342,800	310,900 to 335,700	307,600 to 332,100	304,200 to 328,500	300,900 to 325,000	297,600 to 321,400
11/13-11 $\frac{1}{2}$ to 12 $\frac{1}{2}$	357,100 to 388,200	346,400 to 376,600	342,800 to 372,700	335,700 to 364,900	332,100 to 361,000	328,500 to 357,100	325,000 to 353,300	321,400 to 349,400
10/12-10 $\frac{1}{2}$ to 11 $\frac{1}{2}$	388,200 to 425,200	376,600 to 412,400	372,700 to 408,200	364,900 to 399,700	361,000 to 395,400	357,100 to 391,200	353,300 to 386,900	349,400 to 382,700
9/11-9 $\frac{1}{2}$ to 10 $\frac{1}{2}$	425,200 to 469,900	412,400 to 455,800	408,200 to 451,100	399,700 to 441,700	395,400 to 437,000	391,200 to 433,000	386,900 to 427,600	382,700 to 423,000
16/18-16 $\frac{1}{2}$ to 17 $\frac{1}{2}$	242,300 to 257,100	239,800 to 254,400	237,200 to 251,700	234,700 to 249,000	231,700 to 246,200	229,000 to 243,500	226,200 to 240,200	223,500 to 237,100
15/17-15 $\frac{1}{2}$ to 16 $\frac{1}{2}$	257,100 to 273,600	254,400 to 270,700	251,700 to 267,800	249,000 to 265,000	246,200 to 262,000	243,500 to 259,200	240,200 to 255,900	237,100 to 252,600
14/16-14 $\frac{1}{2}$ to 15 $\frac{1}{2}$	273,600 to 292,500	270,700 to 289,400	267,800 to 286,300	265,000 to 283,300	262,000 to 280,200	259,200 to 277,100	255,900 to 273,600	252,600 to 270,100
13/15-13 $\frac{1}{2}$ to 14 $\frac{1}{2}$	292,500 to 314,200	289,400 to 310,900	286,300 to 307,600	283,300 to 304,200	280,200 to 299,600	277,100 to 297,600	273,600 to 294,100	269,600 to 290,100
12/14-12 $\frac{1}{2}$ to 13 $\frac{1}{2}$	314,200 to 339,200	310,900 to 335,700	307,600 to 332,100	304,200 to 328,500	300,900 to 325,000	297,600 to 321,400	293,600 to 317,900	289,600 to 313,900
11/13-11 $\frac{1}{2}$ to 12 $\frac{1}{2}$	339,200 to 368,800	335,700 to 364,900	332,100 to 361,000	328,500 to 357,100	325,000 to 353,300	321,400 to 349,400	317,400 to 345,400	313,400 to 341,400
10/12-10 $\frac{1}{2}$ to 11 $\frac{1}{2}$	368,800 to 403,900	364,900 to 399,700	361,000 to 395,400	357,100 to 391,200	353,300 to 386,900	349,400 to 382,700	345,400 to 378,700	341,400 to 374,700
9/11-9 $\frac{1}{2}$ to 10 $\frac{1}{2}$	403,900 to 446,400	399,700 to 441,700	395,400 to 437,000	391,200 to 433,000	386,900 to 427,600	382,700 to 423,000	378,700 to 419,000	374,700 to 415,000

TABLE 114. THE DIAMETERS OF THREADS OF DIFFERENT COUNTS.
COTTON YARNS FROM 200'S TO 1'S

Counts	No. in One Inch	Counts	No. in One Inch	Counts	No. in One Inch	Counts	No. in One Inch
200	370	80	234	34	152	13	94 $\frac{1}{3}$
190	361	75	226	32	148	12	90 $\frac{1}{2}$
180	351	70	219	30	143	11	87
170	341	65	211	28	138	10	83
160	331	60	202	26	133	9	79
150	320	55	194	24	128	8	74
140	309	50	185	22	123	7	69
130	297	48	181	20	118	6	64
120	285	46	177	19	114	5	58 $\frac{1}{2}$
110	274	44	173	18	111	4	52 $\frac{1}{3}$
100	261	42	170	17	108	3	45 $\frac{1}{3}$
95	255	40	165	16	104 $\frac{1}{2}$	2	36 $\frac{1}{2}$
90	248	38	162	15	101	1	26 $\frac{3}{20}$
85	241	36	157	14	98	.....	.....

WORSTED YARNS FROM 120'S TO 1'S

Counts	No. in One Inch	Counts	No. in One Inch	Counts	No. in One Inch	Counts	No. in One Inch
120	234	58	163	32	120	13	77
115	229	56	160	30	117	12	74
110	224	54	157	28	113	11	71
105	219	52	154	26	109	10	67
100	213	50	151	24	104	9	64
95	208	48	148	22	100	8	60
90	202	46	145	20	95	7	56
85	197	44	141	19	93	6	52
80	191	42	138	18	90	5	48
75	185	40	135	17	88	4	42 $\frac{2}{3}$
70	179	38	131	16	85	3	37
65	172	36	128	15	83	2	30
60	165	34	124	14	80	1	21 $\frac{1}{3}$

TABLE 114. WOOLEN YARNS (YORKSHIRE SKEIN)—*Continued*

Counts	No. of Threads	Counts	No. of Threads	Counts	No. of Threads	Counts	No. of Threads
1	13.5	14	50.5	27	70.2	40	85.5
2	19.1	15	52.3	28	71.5	42	87.6
3	23.4	16	54.0	29	72.9	44	89.6
4	27.0	17	55.7	30	74.0	46	91.6
5	30.2	18	57.4	31	75.3	48	93.6
6	33.2	19	58.9	32	76.4	50	95.6
7	35.8	20	60.5	33	77.6	52	97.5
8	38.2	21	61.9	34	78.9	54	99.3
9	40.5	22	63.4	35	80.0	56	101.0
10	42.8	23	64.9	36	81.1	58	103.0
11	44.8	24	66.1	37	82.2	60	105.0
12	46.8	25	67.5	38	83.4	.....	.....
13	48.7	26	68.9	39	84.5	.....	.....

NORMAL CONDITION OF TEXTILE MATERIALS

The average relative humidity of the atmosphere is approximately 70 per cent at 65°-70° F. At this relative humidity textile materials are assumed to be in their normal condition.

IN ITS NORMAL CONDITION

Silk	regains approx. 11	% moisture = 1 oz.	9¼	drams per lb.			
Wool	" "	18¼%	"	2 oz.	7½	"	" "
Cotton	" "	8½%	"	1 oz.	4	"	" "
Worsted Yarns	" "	18¼%	"	2 oz.	7½	"	" "
Carded Woolen Yarn	" "	17 %	"	2 oz.	5	"	" "
Worsted and							
Woolen Cloths	" "	16 %	"	2 oz.	3¼	"	" "
Cotton Cloth	" "	6½%	"	0 oz.	14¾	"	" "
Wool Waste	" "	16 %	"	2 oz.	3¼	"	" "
Tops Combed	" "	19 %	"	2 oz.	9	"	" "
with Oil							
Tops Combed							
without Oil	" "	18¼%	"	2 oz.	7½	"	" "
Ordinary Noils	" "	14 %	"	1 oz.	15½	"	" "
Clean Noils	" "	16 %	"	2 oz.	3¼	"	" "
Flax and							
Hemp Yarns	" "	12 %	"	1 oz.	11¼	"	" "
Jute	" "	13¾%	"	1 oz.	14¾	"	" "
Shoddy Yarn	" "	13 %	"	1 oz.	13½	"	" "

Textile material may be made absolutely dry by putting it in a specially constructed oven called a conditioning oven, and submitting it for some time to a current of hot air at a temperature several degrees above the boiling temperature of water. The water contained in the material is vaporized and carried off by the current of hot air. Only the dry fiber and non-volatile portions remain.

If dry material is subjected to an atmosphere containing water vapor, it will absorb or regain moisture. The amount absorbed is generally expressed as the percentage it is of the dry weight, and is called the regain of the material. That is, if 100 pounds of absolutely dry yarn is submitted to an atmosphere containing water vapor and after being allowed to absorb all it will take up at that humidity, weighs 112.5 pounds, the regain is 12.5 per cent.

STANDARD REGAIN

The only standard regain which has been adopted in the United States is for silk, 11 per cent.

In Europe the standard regains are approximately those indicated on preceding page, as normal condition.

TABLE 115. COTTON REGAIN

(Abstracted from the values published by Wm. D. Hartshorne, Trans. Nat'l Ass'n of Cotton Mfrs. No. 90)

DEGREES FAHRENHEIT

Per cent Humidity	35	50	65	75	85	100
	Regain, per cent	Regain, per cent	Regain, per cent	Regain, per cent	Regain, per cent	Regain, per cent
1	0.74	0.72	0.70	0.68	0.67	0.65
5	1.91	1.85	1.80	1.76	1.73	1.68
10	2.72	2.65	2.57	2.53	2.48	2.41
15	3.41	3.30	3.21	3.15	3.09	3.01
20	3.96	3.85	3.74	3.67	3.60	3.50
25	4.49	4.35	4.23	4.15	4.07	3.97
30	4.98	4.83	4.69	4.61	4.52	4.40
35	5.48	5.32	5.17	5.07	4.98	4.85
40	6.00	5.82	5.65	5.55	5.45	5.30
45	6.54	6.35	6.17	6.05	5.94	5.78
50	7.16	6.95	6.75	6.63	6.51	6.33
55	7.84	7.61	7.39	7.25	7.12	6.92
60	8.57	8.31	8.08	7.93	7.78	7.57
65	9.40	9.13	8.86	8.70	8.54	8.31
70	10.31	10.01	9.72	9.54	9.36	9.11
75	11.31	10.98	10.66	10.46	10.27	9.99
80	12.42	12.06	11.71	11.49	11.28	10.98
85	13.70	13.29	12.91	12.67	12.44	12.10
90	15.23	14.78	14.36	14.09	13.83	13.46
95	17.27	16.76	16.28	15.98	15.69	15.26
100	22.07	21.41	20.80	20.41	20.03	19.50

TABLE 116. WORSTED REGAIN

(Abstracted from the values published by Wm. D. Hartshorne, Trans. Nat'l Ass'n of Cotton Mfrs. No. 90)

DEGREES FAHRENHEIT

Per cent Humidity	35	50	65	75	85	100
	Regain, Per cent	Regain, Per cent	Regain, Per cent	Regain, Per cent	Regain, Per cent	Regain, Per cent
1	1.57	1.50	1.44	1.40	1.36	1.31
5	3.63	3.48	3.33	3.23	3.15	3.02
10	5.27	5.04	4.83	4.69	4.57	4.38
15	6.64	6.35	6.08	5.90	5.74	5.52
20	7.83	7.49	7.17	6.97	6.78	6.51
25	8.96	8.57	8.21	7.97	7.76	7.45
30	10.05	9.61	9.20	8.94	8.70	8.35
35	11.12	10.64	10.18	9.90	9.63	9.24
40	12.19	11.65	11.16	10.85	10.54	10.13
45	13.26	12.68	12.14	11.80	11.48	11.02
50	14.37	13.74	13.16	12.79	12.44	11.94
55	15.51	14.83	14.20	13.80	13.43	12.89
60	16.71	15.98	15.30	14.87	14.46	13.88
65	17.96	17.17	16.44	15.98	15.54	14.92
70	19.30	18.46	17.67	17.18	16.71	16.04
75	20.75	19.84	19.00	18.47	17.96	17.24
80	22.35	21.37	20.46	19.89	19.34	18.57
85	24.16	23.10	22.11	21.49	20.91	20.07
90	26.29	25.14	24.07	23.40	22.76	21.85
95	29.11	27.83	26.65	25.90	25.19	24.19
100	36.01	34.43	32.97	32.04	31.17	29.92

TABLE 117. JAPAN RAW SILK REGAIN

REGAIN IN PER CENT AT 70° FAHRENHEIT

(Values interpolated from a curve plotted from experimental data furnished by S. W. Cramer)

Relative Humidity, per cent	Regain, per cent	Relative Humidity, per cent	Regain, per cent
20	7.0	60	11.2
25	7.7	65	11.7
30	8.4	70	12.3
35	9.0	75	13.0
40	9.5	80	13.7
45	10.0	85	14.5
50	10.4	90	15.4
55	10.8		

HUMIDITY, CONDITION AND REGAIN

All textile fibers contain an appreciable percentage of moisture, varying with the humidity of the atmosphere, place of storage, etc.

Water vapor in a given space is saturated when the addition of further vapor would cause condensation into drops and the formation of dew.

The amount of saturated water vapor which can exist in a given space depends upon its temperature.

If the actual amount is less than the amount necessary to saturate the vapor at the existing temperature, the percentage that it is of the saturation amount is called the **RELATIVE HUMIDITY**. For example, the maximum amount of saturated water vapor which can exist in a cubic foot of space at 70° F. is 7.89 grains. If we have a cubic foot of air in which only 3.99 grains of water are suspended there is only half enough water to produce saturated vapor at that temperature and we say that the relative humidity is 50 per cent.

The relative humidity is measured by an apparatus known as a hygrometer or a psychrometer, consisting of a wet-bulb and a dry-bulb thermometer. Circulation of the air past the instrument is absolutely essential for accurate measurements.

The sling psychrometer used by the U. S. Weather Bureau or the Fues Aspiration Psychrometer are typical of the best forms of instrument.

The values given in Table XVII are abstracts from the tables published and used by the United States Weather Bureau with the addition that they have been extended to include both the Centigrade and the Fahrenheit scale. If the hygrometer is graduated in the Centigrade system the difference between the dry and wet bulb temperature (D—W) should be taken from the first column and the value will be found by using the top row of horizontal figures at the head of the columns. Example: Suppose the difference is 4° C. and the wet-bulb temperature 20° C., the relative humidity is 78%. Select the wet-bulb temperature which is nearest to the one found. If the hygrometer is graduated in the Fahrenheit system use the second column for the difference between the dry and wet bulb reading (D—W). Example: Suppose the difference is 9.4° F. and the wet-bulb temperature is 79° F., the relative humidity is 74.0%.

TABLE 118. RELATIVE HUMIDITY
TEMPERATURE, CENTIGRADE AND FAHRENHEIT

Difference between the Dry and Wet Bulb Thermometer, D-W		TEMPERATURE BY WET BULB THERMOMETER = W					
		0° C. 32° F.	10° C. 50° F.	15° C. 59° F.	20° C. 68° F.	25° C. 77° F.	30° C. 86° F.
Cent. Deg.	Fahr. Deg.	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
0.0	0.0	100	100	100	100	100	100
0.2	0.4	99	99	99	99	99	99
0.4	0.7	97	97	97	98	98	98
0.6	1.1	96	96	96	96	97	97
0.8	1.4	94	95	95	95	95	96
1.0	1.8	93	94	94	94	94	94
1.2	2.2	92	92	93	93	93	93
1.4	2.5	90	91	91	92	92	92
1.6	2.9	89	90	90	91	91	91
1.8	3.2	88	89	89	90	90	90
2.0	3.6	87	88	88	88	89	89
2.2	4.0	85	86	87	87	88	88
2.4	4.3	84	86	86	86	87	87
2.6	4.7	83	84	85	85	86	86
2.8	5.0	82	83	84	84	85	85
3.0	5.4	81	82	83	83	84	84
3.2	5.8	80	81	82	82	83	83
3.4	6.1	79	80	81	81	82	82
3.6	6.5	77	79	80	80	81	82
3.8	6.8	76	78	79	79	80	81
4.0	7.2	75	77	78	78	79	80
4.2	7.6	74	76	77	77	78	79
4.4	7.9	73	75	76	77	77	78
4.6	8.3	72	74	75	76	76	77
4.8	8.6	71	73	74	75	75	76
5.0	9.0	70	72	73	74	75	75
5.2	9.4	69	71	72	73	74	75
5.4	9.7	68	70	71	72	73	74
5.6	10.1	67	69	70	71	72	73
5.8	10.4	66	69	69	70	71	72

TABLE 118. RELATIVE HUMIDITY—*Continued*

TEMPERATURE, CENTIGRADE AND FAHRENHEIT

Difference between the Dry and Wet Bulb Thermometer, D-W		TEMPERATURE BY WET BULB THERMOMETER = W					
		0° C. 32° F.	10° C. 50° F.	15° C. 59° F.	20° C. 68° F.	25° C. 77° F.	30° C. 86° F.
Cent. Deg.	Fahr. Deg.	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
6.0	10.8	66	68	69	70	70	71
6.2	11.2	65	67	68	69	70	71
6.4	11.5	64	66	67	68	69	70
6.6	11.9	63	65	66	67	68	69
6.8	12.2	62	64	65	66	67	68
7.0	12.6	61	63	65	66	67	68
7.2	13.0	60	63	64	65	66	67
7.4	13.3	60	62	63	64	65	66
7.6	13.7	59	61	62	63	64	65
7.8	14.0	58	60	62	63	64	65
8.0	14.4	57	60	61	62	63	64
8.2	14.8	56	59	60	61	62	63
8.4	15.1	56	58	59	60	62	63
8.6	15.5	55	57	58	60	61	62
8.8	15.8	54	57	58	59	60	61
9.0	16.2	53	56	57	58	60	61
9.2	16.6	53	55	57	58	59	60
9.4	16.9	52	55	56	57	58	59
9.6	17.3	51	54	55	56	58	59
9.8	17.6	51	53	55	56	57	58
10.0	18.0	50	53	54	55	56	57
10.5	18.9	48	51	52	54	55	.....
11.0	19.8	47	49	51	52	53	.....
11.5	20.7	45	48	49	51	52	.....
12.0	21.6	44	47	48	49	50	.....
12.5	22.5	42	45	46	48	49	.....
13.0	23.4	41	44	45	46	48	.....
13.5	24.3	40	43	44	45	46	.....

TABLE 118. RELATIVE HUMIDITY—*Continued*

TEMPERATURE, CENTIGRADE AND FAHRENHEIT

Difference between the Dry and Wet Bulb Thermometer, D-W		TEMPERATURE BY WET BULB THERMOMETER = W					
		0° C. 32° F.	10° C. 50° F.	15° C. 59° F.	20° C. 68° F.	25° C. 77° F.	30° C. 86° F.
Cent. Deg.	Fahr. Deg.	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
14.0	25.2	38	41	43	44	45	.....
14.5	26.1	37	40	41	43	44	.....
15.0	27.0	36	39	40	42	.....	.....
15.5	27.9	35	38	39	40	.....	.....
16.0	28.8	34	37	38	39	.....	.....
16.5	29.7	33	36	37	38	.....	.....
17.0	30.6	32	35	36	37	.....	.....
17.5	31.5	31	34	35	36	.....	.....
18.0	32.4	30	33	34	35	.....	.....
18.5	33.3	29	32	33	34	.....	.....
19.0	34.2	28	31	32	33	.....	.....
19.5	35.1	27	30	31	33	.....	.....
20.0	36.0	26	29	30	32	.....	.....
21.0	37.8	25	27	29	.....	.....	.....
22.0	39.6	23	26	27	.....	.....	.....
23.0	41.4	22	24	26	.....	.....	.....
24.0	43.2	21	23	24	.....	.....	.....
25.0	45.0	19	22	23	.....	.....	.....
26.0	46.8	18	21	.....	.....	.....	.....
27.0	48.6	17	20	.....	.....	.....	.....
28.0	50.4	16	19	.....	.....	.....	.....
29.0	52.2	15	18	.....	.....	.....	.....
30.0	54.0	14	17	.....	.....	.....	.....

TABLE 119. HEAT

Conversion of Thermometer Readings

F°	C°	F°	C°	F°	C°	F°	C°	F°	C°	F°	C°
-40	-40.00	30	-1.11	80	26.67	250	121.11	500	260.00	900	482.22
-38	-38.89	31	-0.56	81	27.22	255	123.89	505	262.78	910	487.78
-36	-37.78	32	0.00	82	27.78	260	126.67	510	265.56	920	493.33
-34	-36.67	33	0.56	83	28.33	265	129.44	515	268.33	930	498.89
-32	-35.56	34	1.11	84	28.89	270	132.22	520	271.11	940	504.44
-30	-34.44	35	1.67	85	29.44	275	135.00	525	273.89	950	510.00
-28	-33.33	36	2.22	86	30.00	280	137.78	530	276.67	960	515.56
-26	-32.22	37	2.78	87	30.56	285	140.55	535	279.44	970	521.11
-24	-31.11	38	3.33	88	31.11	290	143.33	540	282.22	980	526.67
-22	-30.00	39	3.89	89	31.67	295	146.11	545	285.00	990	532.22
-20	-28.89	40	4.44	90	32.22	300	148.89	550	287.78	1000	537.78
-18	-27.78	41	5.00	91	32.78	305	151.67	555	290.55	1050	555.56
-16	-26.67	42	5.56	92	33.33	310	154.44	560	293.33	1100	593.33
-14	-25.56	43	6.11	93	33.89	315	157.22	565	296.11	1150	621.11
-12	-24.44	44	6.67	94	33.44	320	160.00	570	298.89	1200	648.89
-10	-23.33	45	7.22	95	35.00	325	162.78	575	301.67	1250	676.67
-8	-22.22	46	7.78	96	35.56	330	165.56	580	304.44	1300	704.44
-6	-21.11	47	8.33	97	36.11	335	168.33	585	307.22	1350	732.22
-4	-20.00	48	8.89	98	36.67	340	171.11	590	310.00	1400	760.00
-2	-18.89	49	9.44	99	37.22	345	173.89	595	312.78	1450	787.78
0	-17.78	50	10.00	100	37.78	350	176.67	600	315.56	1500	815.56
1	-17.22	51	10.56	105	40.55	355	179.44	610	321.11	1550	843.33
2	-16.67	52	11.11	110	43.33	360	182.22	620	326.67	1600	871.11
3	-16.11	53	11.67	115	46.11	365	185.00	630	332.22	1650	898.89
4	-15.56	54	12.22	120	48.89	370	187.78	640	337.78	1700	926.67
5	-15.00	55	12.78	125	51.67	375	190.55	650	343.33	1750	954.44
6	-14.44	56	13.33	130	54.44	380	193.33	660	348.89	1800	982.22
7	-13.89	57	13.89	135	57.22	385	196.11	670	354.44	1850	1010.00
8	-13.33	58	14.44	140	60.00	390	198.89	680	360.00	1900	1037.78
9	-12.78	59	15.00	145	62.78	395	201.67	690	365.56	1950	1065.56
10	-12.22	60	15.56	150	65.56	400	204.44	700	371.11	2000	1093.33
11	-11.67	61	16.11	155	68.33	405	207.22	710	376.67	2050	1121.11
12	-11.11	62	16.67	160	71.11	410	210.00	720	382.22	2100	1148.89
13	-10.56	63	17.22	165	73.89	415	212.78	730	387.78	2150	1176.67
14	-10.00	64	17.78	170	76.67	420	215.56	740	393.33	2200	1204.44
15	-9.44	65	18.33	175	79.44	425	218.33	750	398.89	2250	1232.22
16	-8.89	66	18.89	180	82.22	430	221.11	760	404.44	2300	1260.00
17	-8.33	67	19.44	185	85.00	435	223.89	770	410.00	2350	1287.78
18	-7.78	68	20.00	190	87.78	440	226.67	780	415.56	2400	1315.56
19	-7.22	69	20.56	195	90.55	445	229.44	790	421.11	2450	1343.33
20	-6.67	70	21.11	200	93.33	450	232.22	800	426.67	2500	1371.11
21	-6.11	71	21.67	205	96.11	455	235.00	810	432.22	2550	1398.89
22	-5.56	72	22.22	210	98.89	460	237.78	820	437.78	2600	1426.67
23	-5.00	73	22.78	215	101.67	465	240.55	830	443.33	2650	1454.44
24	-4.44	74	23.33	220	104.44	470	243.33	840	448.89	2700	1482.22
25	-3.89	75	23.89	225	107.22	475	246.11	850	454.44	2750	1510.00
26	-3.33	76	24.44	230	110.00	480	248.89	860	460.00	2800	1537.78
27	-2.78	77	25.00	235	112.78	485	251.67	870	465.56	2850	1565.56
28	-2.22	78	25.56	240	115.56	490	254.44	880	471.11	2900	1593.33
29	-1.67	79	26.11	245	118.33	495	257.22	890	476.67	2950	1621.11

6 1/2	39,385	3 1/4	39,385	48	40,330	40,000	72	40,320	25	40,000	134	40,200
6	42,667	3	42,667	50	42,000	42,000	76	42,560	26	41,600	140	42,000
5 1/4	44,522	2 3/4	46,545	52	43,680	44,000	78	43,680	28	44,800	146	43,800
5 1/2	46,545	2 1/2	51,200	54	45,360	46,000	82	45,920	29	46,400	154	46,200
5 1/4	48,762	2 1/2	51,200	58	48,720	48,000	86	48,160	30	48,000	160	48,000
5	51,200	2 1/2	51,200	60	50,400	50,000	90	50,400	31	49,600	166	49,800
4 7/8	52,512	2 1/2	51,200	62	52,080	52,000	92	51,520	32	51,200	174	52,200
4 3/4	53,895	2 1/4	56,889	64	53,760	54,000	96	53,760	34	54,000	180	54,000
4 3/8	55,351	2 1/4	56,889	66	55,440	56,000	100	56,000	35	56,000	186	55,800
4 3/8	58,514	2 1/4	56,889	70	58,660	58,000	104	58,240	36	57,600	194	58,200
4 1/4	60,235	2 1/4	56,889	72	60,480	60,000	108	60,480	38	60,800	200	60,000
4 1/4	62,060	2 1/4	56,889	74	62,160	62,000	110	61,600	39	62,400	206	61,800
4 1/8	64,000	2	64,000	76	63,840	64,000	114	63,840	40	64,000	214	64,200
4	66,065	2	64,000	78	65,520	66,000	118	66,080	41	65,600	220	66,000
3 7/8	68,267	2	64,000	80	67,200	68,000	122	68,320	42	67,200	226	67,800
3 3/4	70,621	2	64,000	84	70,560	70,000	126	70,560	44	70,400	234	70,200
3 3/8	73,142	2	64,000	86	72,240	72,000	128	71,680	45	72,000	240	72,000
3 1/2	75,852	2	64,000	88	73,920	74,000	132	73,920	46	73,800	246	73,800
3 1/4	78,709	2	64,000	90	75,600	76,000	136	76,160	48	76,800	254	76,200
3 1/4	81,920	2	64,000	92	77,280	78,000	140	78,400	49	78,400	260	78,000
3 1/8	85,333	2	64,000	96	80,640	80,000	142	79,520	50	80,000	266	79,800
3	89,043	2	64,000	100	82,320	82,000	146	81,760	51	81,600	274	82,200
2 7/8	93,091	2	64,000	102	84,000	84,000	150	84,000	52	83,200	280	84,000
2 3/4	97,524	2	64,000	104	85,680	86,000	154	86,240	54	86,400	286	85,800
2 3/8	102,400	2	64,000	108	87,360	88,000	158	88,480	55	88,000	294	88,200
2 3/8	107,789	2	64,000	110	89,720	90,000	160	89,600	56	89,600	300	90,000
2 1/8	120,471	2	64,000	114	92,400	92,000	164	91,840	58	92,800	306	91,800
2	136,533	2	64,000	120	95,760	96,000	172	96,320	60	96,000	320	96,000
1 7/8	146,286	2	64,000	126	100,800	100,000	180	100,800	62	99,200	330	99,000
1 3/4	170,667	2	64,000	130	109,200	110,000	200	112,000	69	110,400	370	111,000
1 1/2	186,182	2	64,000	134	119,280	120,000	210	117,600	75	120,000	400	120,000
1 1/4	204,800	2	64,000	142	129,360	130,000	230	128,800	80	128,000	430	129,000
1 1/4	227,556	2	64,000	154	139,440	140,000	250	140,000	90	144,000	470	141,000
1 1/8	256,000	2	64,000	166	149,520	150,000						
1 1/8	292,571	2	64,000	178	168,000	170,000						
1 1/8	341,333	2	64,000	200	193,200	190,000						
1 1/8	409,600	2	64,000	230	207,250	200,000						
1 1/8	512,000	2	64,000	240	229,000	225,000						
1 1/8	682,667	2	64,000	270	252,000	250,000						
1 1/8	870,500	2	64,000	300	300,000	300,000						
1 1/8	1,024,000	2	64,000	350,000	350,000	350,000						
1 1/8		2	64,000	400,000	400,000	400,000						
1 1/8		2	64,000	500,000	500,000	500,000						
1 1/8		2	64,000	600,000	600,000	600,000						
1 1/8		2	64,000	800,000	800,000	800,000						
1 1/8		2	64,000	1,000,000	1,000,000	1,000,000						

2 ply, 3 ply and 4 ply Cotton, Worsted, Woolen and Linen Yarns, have respectively 1/2, 1/4 and 1/4 the number of hanks per pound and yardage their counts or numbers indicate.
 SPUN SILK YARNS, however, in 2 ply, 3 ply, etc., have the number of hanks per pound and yardage their counts indicate, and are written 20/2, 30/2, 20/3, 30/3, etc.
 Corresponding counts and yardage are on the same line running across the table.

TABLE 121. EQUIVALENTS OF TWADDLE, BAUMÉ AND SPECIFIC GRAVITY SCALES

Twaddle	Baumé	Specific Gravity	Twaddle	Baumé	Specific Gravity	Twaddle	Baumé	Specific Gravity	Twaddle	Baumé	Specific Gravity
0	0	1.000	44	26.0	1.220	88	44.1	1.440	131	57.1	1.655
1	0.7	1.005	45	26.4	1.225	89	44.4	1.445	132	57.4	1.660
2	1.4	1.010	46	26.9	1.230	90	44.8	1.450	133	57.7	1.665
3	2.1	1.015	47	27.4	1.235	91	45.1	1.455	134	57.9	1.670
4	2.7	1.020	48	27.9	1.240	92	45.4	1.460	135	58.2	1.675
5	3.4	1.025	49	28.4	1.245	93	45.8	1.465	136	58.4	1.680
6	4.1	1.030	50	28.8	1.250	94	46.1	1.470	137	58.7	1.685
7	4.7	1.035	51	29.3	1.255	95	46.4	1.475	138	58.9	1.690
8	5.4	1.040	52	29.7	1.260	96	46.8	1.480	139	59.2	1.695
9	6.0	1.045	53	30.2	1.265	97	47.1	1.485	140	59.5	1.700
10	6.7	1.050	54	30.6	1.270	98	47.4	1.490	141	59.7	1.705
11	7.4	1.055	55	31.1	1.275	99	47.8	1.495	142	60.0	1.710
12	8.0	1.060	56	31.5	1.280	100	48.1	1.500	143	60.2	1.715
13	8.7	1.065	57	32.0	1.285	101	48.4	1.505	144	60.4	1.720
14	9.4	1.070	58	32.4	1.290	102	48.7	1.510	145	60.6	1.725
15	10.0	1.075	59	32.8	1.295	103	49.0	1.515	146	60.9	1.730
16	10.6	1.080	60	33.3	1.300	104	49.4	1.520	147	61.1	1.735
17	11.2	1.085	61	33.7	1.305	105	49.7	1.525	148	61.4	1.740
18	11.9	1.090	62	34.2	1.310	106	50.0	1.530	149	61.6	1.745
19	12.4	1.095	63	34.6	1.315	107	50.3	1.535	150	61.8	1.750
20	13.0	1.100	64	35.0	1.320	108	50.6	1.540	151	62.1	1.755
21	13.6	1.105	65	35.4	1.325	109	50.9	1.545	152	62.3	1.760
22	14.2	1.110	66	35.8	1.330	110	51.2	1.550	153	62.5	1.765
23	14.9	1.115	67	36.2	1.335	111	51.5	1.555	154	62.8	1.770
24	15.4	1.120	68	36.6	1.340	112	51.8	1.560	155	63.0	1.775
25	16.0	1.125	69	37.0	1.345	113	52.1	1.565	156	63.2	1.780
26	16.5	1.130	70	37.4	1.350	114	52.4	1.570	157	63.5	1.785
27	17.1	1.135	71	37.8	1.355	115	52.7	1.575	158	63.7	1.790
28	17.7	1.140	72	38.2	1.360	116	53.0	1.580	159	64.0	1.795
29	18.3	1.145	73	38.6	1.365	117	53.3	1.585	160	64.2	1.800
30	18.8	1.150	74	39.0	1.370	118	53.6	1.590	161	64.4	1.805
31	19.3	1.155	75	39.4	1.375	119	53.9	1.595	162	64.6	1.810
32	19.8	1.160	76	39.8	1.380	120	54.1	1.600	163	64.8	1.815
33	20.3	1.165	77	40.1	1.385	121	54.4	1.605	164	65.0	1.820
34	20.9	1.170	78	40.5	1.390	122	54.7	1.610	165	65.2	1.825
35	21.4	1.175	79	40.8	1.395	123	55.0	1.615	166	65.5	1.830
36	22.0	1.180	80	41.2	1.400	124	55.2	1.620	167	65.7	1.835
37	22.5	1.185	81	41.6	1.405	125	55.5	1.625	168	65.9	1.840
38	23.0	1.190	82	42.0	1.410	126	55.8	1.630	169	66.1	1.845
39	23.5	1.195	83	42.3	1.415	127	56.0	1.635	170	66.3	1.850
40	24.0	1.200	84	42.7	1.420	128	56.3	1.640	171	66.5	1.855
41	24.5	1.205	85	43.1	1.425	129	56.6	1.645	172	66.7	1.860
42	25.0	1.210	86	43.4	1.430	130	56.9	1.650	173	67.0	1.865
43	25.5	1.215	87	43.8	1.435	...	...	...	...	...	...

8. Artificial Silk Yarns.—The size or count of artificial silk is expressed in deniers corresponding to the number of grains in a length of 9000 meters. This is very close to the Lyons denier.

Dorgin¹ gives the following table for the counts of artificial silk:

TABLE 122. ARTIFICIAL SILK COUNTS

Denier	Yards per Pound	Denier	Yards per Pound	Denier	Yards per Pound	Denier	Yards per Pound
50	89,201	150	29,764	250	17,858	350	12,756
60	74,409	160	27,903	260	17,171	360	12,401
70	63,779	170	26,262	270	16,535	370	12,066
80	55,807	180	24,803	280	15,945	380	11,749
90	49,606	190	23,497	290	15,395	390	11,447
100	44,645	200	22,323	300	14,882	400	11,161
110	40,587	210	21,260	310	14,402	450	9,921
120	37,204	220	20,293	320	13,952	500	8,929
130	34,342	230	19,411	330	13,529	550	8,118
140	31,889	240	18,602	340	13,131	600	7,441

Artificial silk involves the question of specific gravity which cannot be compared with the specific gravity of real silk; artificial silk, as well known, will cover less for a given unit than real silk, for which reason allowance must be made for this property.

The following table gives the corresponding counts of yarns of similar size (yards per pound) of artificial silk, thrown silk, cotton and spun silk:

Cotton 2-ply, 3-ply, and 4-ply has $\frac{1}{2}$, $\frac{1}{3}$, and $\frac{1}{4}$ the number of hanks and yardage per pound its counts and numbers indicate. For instance, $1/10 = 4200$ yds. to the pound, $3/10 = 2800$ yds.

Spun silk in 2-ply, 3-ply, etc., has the number of hanks per pound and yardage its count indicates. For instance, $10/1 = 8400$ yds. to pound, $10/2$ the same, etc.

Thrown silk loses in dyeing, in average 25 per cent, hence 1 lb. or 16 ozs. gray will give 12 ozs. dyed, pure dye, making it necessary to add $33\frac{1}{3}$ per cent to the gum or gray yards per pound to obtain the dyed yardage per pound of 16 ounces: thus, 46 drams 5565 yds. per gum pound, plus $33\frac{1}{3}$ per cent = 1855 = 7420 yds per dyed pound.

¹ American Silk Journal.

TABLE 123. ARTIFICIAL SILK YARNS

Artificial Silk		Thrown Silk			Cotton and Spun Silk Singles, 840 Yards per Hank	
Deniers	Yards per Pound	Drams	Yards per Pound in Gum	Yards per Pound in Boil-off	No.	Yards per Pound
60	74,409	4 $\frac{1}{2}$	56,889	75,852	90	75,600
70	63,779	5 $\frac{3}{8}$	47,628	63,504	76	63,840
80	55,806	6 $\frac{1}{8}$	41,796	55,728	66	55,440
90	49,606	6 $\frac{7}{8}$	37,236	49,648	60	50,400
100	44,645	7 $\frac{5}{8}$	33,572	44,762	54	45,360
110	40,587	8 $\frac{3}{8}$	30,568	40,757	48	40,320
120	37,204	9 $\frac{1}{8}$	28,055	37,407	46	38,640
130	34,342	9 $\frac{7}{8}$	25,924	34,565	41	34,440
140	31,800	10 $\frac{3}{4}$	23,814	31,752	38	31,920
150	29,764	11 $\frac{1}{2}$	22,260	29,680	35	29,400
160	27,903	12 $\frac{1}{4}$	20,898	27,864	33	27,720
170	26,662	13	19,692	26,256	31	26,040
180	24,803	13 $\frac{3}{4}$	18,618	24,824	29	24,360
190	23,497	14 $\frac{1}{2}$	17,655	23,540	28	23,520
200	22,323	15 $\frac{1}{4}$	16,786	22,381	27	22,680
210	21,260	16	16,000	21,333	26	21,840
220	20,293	16 $\frac{3}{4}$	15,284	20,378	24	20,160
230	19,411	17 $\frac{1}{2}$	14,628	19,504	23	19,320
240	18,602	18 $\frac{1}{4}$	14,028	18,704	22	18,480
250	17,858	19	13,474	17,965	21	17,640
260	17,171	20	12,800	17,067	20	16,800
270	16,535	20 $\frac{3}{4}$	12,337	16,449	.....	.....
280	15,945	21 $\frac{1}{2}$	11,907	15,876	19	15,960
290	15,395	22	11,636	15,515	18	15,120
300	14,882	23	11,130	14,840	.....	.....
310	14,401	23 $\frac{1}{2}$	10,894	14,525	17	14,280
320	13,951	24 $\frac{1}{2}$	10,449	13,932	16	13,440
330	13,529	25	10,240	13,653	.....	.....
340	13,131	26	9,846	13,128	.....	.....
350	12,756	26 $\frac{1}{2}$	9,663	12,883	15	12,600
360	12,401	27 $\frac{1}{2}$	9,309	12,412	.....	.....
370	12,066	28 $\frac{1}{2}$	8,983	11,977	.....	.....
380	11,749	29	8,827	11,769	14	11,760
390	11,447	30	8,533	11,378	.....	.....
400	11,161	30 $\frac{1}{2}$	8,393	11,191	13	10,920
450	9,921	34 $\frac{1}{2}$	7,421	9,894	12	10,080
500	8,929	38	6,737	8,983	11	9,240
550	8,117	42	6,095	8,127	10	8,400
600	7,441	46	5,565	7,420	9	7,560

VALUE PROPORTIONS FOR THROWN SILK

AT VARIOUS RATES OF BOIL-OFF

Wrong calculations in comparing the values of a certain quality of thrown silks at different rates of boil-off are apt to cause unpleasant surprises. For instance, a dealer in thrown silk will offer a buyer 100 pounds boil-off at 26 per cent., at say, \$4.70 per pound. Another dealer offers the same buyer the same quality of thrown silk, boiling off 18 per cent., at \$5.21. The buyer in comparing these two prices would naturally be inclined to buy the \$4.70 silk if he is not well posted regarding the question of boil-off. If the last dealer inquires what the boil-off is on the silk offered by the first dealer, the buyer would generally reply that while there is a difference of 8 per cent in the rate of boil-off, even so the price of the second dealer compares unfavorably with that of the first dealer.

Many people might figure that if 8 per cent for the difference in boil-off is added to the price of the thrown silk offered by the first dealer, the buyer would still be getting his silk at a less price than that offered by the second dealer; to wit, he would be paying \$4.70 plus 8 per cent, or \$5.07 instead of \$5.21, as offered by the second dealer.

There might be a number of buyers of thrown silk figuring this way, and they would be wrong. A silk boiling off 26 per cent and selling at \$4.70 per pound is exactly equal to silk boiling off at 18 per cent and selling at \$5.22 per pound.

The following table of value proportions for thrown silk at various rates of boil-off will be found valuable in making calculations of this kind:

TABLE 124. COMPARATIVE VALUE IN DOLLARS OF ONE POUND OF SILK AT VARIOUS RATES OF BOIL-OFF

18%	19%	20%	21%	22%	23%	24%	25%	26%	27%	28%	29%	30%
3.00	2.96	2.93	2.90	2.85	2.81	2.78	2.74	2.71	2.67	2.64	2.60	2.56
3.02 ½	2.98 ½	2.95	2.92	2.87	2.83	2.80	2.76	2.73	2.69	2.66	2.62	2.58
3.05	3.01	2.98	2.95	2.90	2.86	2.83	2.79	2.76	2.72	2.69	2.65	2.61
3.07 ½	3.03 ½	3.00	2.97	2.92	2.88	2.85	2.81	2.78	2.74	2.71	2.67	2.63
3.10	3.06	3.03	3.00	2.95	2.90	2.88	2.84	2.81	2.77	2.74	2.70	2.66
3.12 ½	2.08 ½	3.05	3.02	2.97	2.93	2.90	2.86	2.83	2.79	2.76	2.72	2.68
3.15	3.11	3.08	3.05	3.00	2.95	2.93	2.89	2.86	2.82	2.79	2.75	2.71
3.17 ½	3.13 ½	3.10	3.07	3.02	2.98	2.95	2.91	2.88	2.84	2.81	2.77	2.73
3.20	3.16	3.13	3.10	3.05	3.01	2.98	2.94	2.91	2.87	2.84	2.80	2.76
3.22 ½	3.18 ½	3.15	3.12	3.07	3.03	3.00	2.96	2.93	2.89	2.86	2.82	2.78
3.25	3.21	3.18	3.15	3.10	3.06	3.02	2.98	2.95	2.91	2.88	2.84	2.80
3.27 ½	3.23 ½	3.20	3.17	3.12	3.08	3.04	3.00	2.97	2.93	2.90	2.86	2.82
3.30	3.26	3.23	3.20	3.15	3.11	3.07	3.03	2.99	2.95	2.92	2.88	2.84
3.32 ½	3.28 ½	3.25	3.22	3.17	3.13	3.09	3.05	3.01	2.97	2.95	2.91	2.87
3.35	3.31	3.28	3.25	3.20	3.10	3.12	3.08	3.02	3.00	2.98	2.93	2.89
3.37 ½	3.33 ½	3.30	3.27	3.22	3.18	3.14	3.10	3.06	3.02	3.00	2.95	2.91
3.40	3.36	3.33	3.30	3.25	3.21	3.17	3.13	3.09	3.04	3.01	2.97	2.93
3.42 ½	3.38	3.35	3.32	3.27	3.23	3.19	3.15	3.11	3.06	3.02	2.98	2.94
3.45	3.40 ½	3.38	3.35	3.29	3.25	3.21	3.17	3.13	3.08	3.04	2.99	2.96
3.47 ½	3.43 ½	3.40	3.37	3.31	3.27	3.23	3.19	3.15	3.10	3.06	3.01	2.90
3.50	3.45 ½	3.42	3.39	3.33	3.29	3.25	3.21	3.17	3.12	3.08	3.03	3.01
3.52 ½	3.48	3.45	3.42	3.36	3.32	3.28	3.23	3.19	3.14	3.10	3.05	3.03
3.55	3.51	3.48	3.45	3.39	3.35	3.31	3.26	3.22	3.17	3.13	3.08	3.05
3.57 ½	3.53	3.50	3.47	3.41	3.37	3.33	3.28	3.24	3.19	3.15	3.10	3.07
3.60	3.55 ½	3.52	3.49	3.43	3.39	3.35	3.30	3.25	3.20	3.16	3.13	3.08
3.62 ½	3.58	3.54	3.51	3.45	3.41	3.37	3.32	3.27	3.22	3.18	3.15	3.10
3.65	3.60 ½	3.56	3.53	3.47	3.43	3.39	3.34	3.29	3.24	3.20	3.16	3.12
3.67 ½	3.63	3.58	3.55	3.49	3.45	3.42	3.37	3.32	3.27	3.23	3.18	3.15
3.70	3.65 ½	3.60	3.57	3.51	3.47	3.44	3.39	3.34	3.29	3.25	3.20	3.17
3.72 ½	3.68	3.63	3.60	3.54	3.50	3.47	3.42	3.37	3.32	3.28	3.23	3.20
3.75	3.70 ½	3.66	3.63	3.57	3.53	3.49	3.44	3.39	3.34	3.30	3.25	3.22
3.77 ½	3.73	3.69	3.66	3.60	3.56	3.51	3.46	3.41	3.36	3.32	3.27	3.24
3.80	3.75 ½	3.71	3.68	3.62	3.58	3.53	3.48	3.43	3.38	3.34	3.29	3.26
3.82 ½	3.78	3.73	3.70	3.64	3.60	3.55	3.50	3.45	3.40	3.36	3.31	3.28
3.85	3.80	3.76	3.72	3.66	3.61	3.57	3.52	3.47	3.42	3.38	3.33	3.30
3.87 ½	3.82 ½	3.78	3.73	3.68	3.63	3.59	3.54	3.49	3.44	3.40	3.35	3.32
3.90	3.85	3.81	3.75	3.70	3.65	3.61	3.56	3.51	3.46	3.42	3.37	3.34
3.92 ½	3.87 ½	3.83	3.77	3.72	3.67	3.63	3.58	3.53	3.48	3.44	3.39	3.36
3.95	3.90	3.86	3.80	3.75	3.70	3.65	3.60	3.55	3.50	3.46	3.41	3.37
3.97 ½	3.92 ½	3.88	3.82	3.77	3.72	3.67	3.62	3.57	3.52	3.48	3.43	3.39
4.00	3.95	3.90	3.85	3.80	3.75	3.70	3.65	3.60	3.55	3.50	3.45	3.41
4.02 ½	3.97	3.93	3.87	3.82	3.77	3.72	3.67	3.62	3.57	3.52	3.47	3.43
4.05	4.00	3.96	3.90	3.85	3.80	3.75	3.70	3.65	3.60	3.54	3.49	3.45
4.07 ½	4.02	3.98	3.92	3.87	3.82	3.77	3.72	3.67	3.62	3.56	3.51	3.47
4.10	4.05	4.01	3.95	3.90	3.85	3.80	3.75	3.70	3.65	3.59	3.54	3.50
4.12 ½	4.07	4.03	3.97	3.92	3.87	3.82	3.77	3.72	3.67	3.61	3.56	3.52
4.15	4.10	4.06	4.00	3.95	3.90	3.85	3.80	3.75	3.70	3.64	3.59	3.55
4.17 ½	4.12	4.08	4.02	3.97	3.92	3.87	3.82	3.77	3.72	3.67	3.62	3.58
4.20	4.15	4.11	4.05	4.00	3.94	3.90	3.85	3.79	3.74	3.69	3.64	3.60
4.22 ½	4.17	4.13	4.07	4.02	3.96	3.92	3.87	3.81	3.76	3.72	3.67	3.63
4.25	4.20	4.16	4.10	4.05	4.00	3.94	3.90	3.84	3.79	3.74	3.69	3.65
4.27 ½	4.22	4.18	4.12	4.07	4.02	3.96	3.92	3.86	3.81	3.76	3.71	3.67
4.30	4.25	4.21	4.15	4.10	4.04	3.99	3.95	3.89	3.83	3.78	3.73	3.69
4.32 ½	4.27	4.23	4.17	4.12	4.06	4.01	3.97	3.91	3.85	3.80	3.75	3.71
4.35	4.29	4.25	4.20	4.14	4.08	4.03	3.99	3.93	3.87	3.82	3.77	3.73
4.37 ½	4.31	4.27	4.22	4.16	4.10	4.05	4.01	3.95	3.90	3.85	3.80	3.76
4.40	4.34	4.30	4.25	4.19	4.13	4.07	4.03	3.97	3.92	3.87	3.82	3.78
4.42 ½	4.36	4.32	4.27	4.21	4.15	4.10	4.05	3.99	3.94	3.90	3.85	3.81
4.45	4.39	4.35	4.30	4.24	4.18	4.12	4.07	4.01	3.97	3.92	3.87	3.83
4.47 ½	4.41	4.37	4.32	4.26	4.20	4.15	4.10	4.03	3.99	3.95	3.89	3.86
4.50	4.44	4.40	4.35	4.29	4.23	4.17	4.12	4.05	4.00	3.96	3.91	3.88

TABLE 124. COMPARATIVE VALUE IN DOLLARS OF ONE POUND OF SILK AT VARIOUS RATES OF BOIL-OFF—*Continued*

18%	19%	20%	21%	22%	23%	24%	25%	26%	27%	28%	29%	30%
4.52½	4.46	4.42	4.37	4.31	4.25	4.20	4.15	4.08	4.02	3.98	3.93	3.90
4.55	4.49	4.45	4.40	4.34	4.27	4.23	4.17	4.10	4.04	4.00	3.95	3.92
4.57½	4.51	4.47	4.42	4.36	4.29	4.25	4.20	4.13	4.07	4.02	3.97	3.94
4.60	4.54	4.50	4.45	4.39	4.32	4.27	4.22	4.16	4.10	4.05	4.00	3.96
4.62½	4.56	4.52	4.47	4.41	4.34	4.30	4.25	4.19	4.13	4.07	4.02	3.98
4.65	4.59	4.55	4.50	4.44	4.37	4.32	4.27	4.21	4.15	4.09	4.04	4.00
4.67½	4.61	4.57	4.52	4.46	4.39	4.34	4.29	4.23	4.17	4.11	4.06	4.02
4.70	4.64	4.60	4.55	4.49	4.42	4.37	4.32	4.26	4.20	4.13	4.08	4.04
4.72½	4.66	4.62	4.57	4.51	4.44	4.39	4.34	4.28	4.22	4.15	4.10	4.06
3.75	4.69	4.65	4.59	4.53	4.46	4.41	4.36	4.29	4.23	4.17	4.12	4.07
4.77½	4.71	4.67	4.61	4.55	4.48	4.43	4.38	4.31	4.25	4.19	4.13	4.09
4.80	4.74	4.70	4.63	4.57	4.50	4.45	4.40	4.33	4.27	4.21	4.15	4.10
4.82½	4.77	4.72	4.65	4.59	4.53	4.47	4.42	4.35	4.30	4.24	4.17	4.12
4.85	4.80	4.74	4.68	4.62	4.56	4.50	4.44	4.38	4.33	4.27	4.20	4.15
4.87½	4.82	4.77	4.71	4.65	4.59	4.53	4.47	4.41	4.36	4.30	4.23	4.18
4.90	4.85	4.79	4.73	4.67	4.61	4.55	4.49	4.43	4.38	4.32	4.25	4.20
4.92½	4.87	4.81	4.75	4.69	4.63	4.57	4.51	4.45	4.40	4.34	4.27	4.22
4.95	4.90	4.84	4.78	4.72	4.66	4.60	4.54	4.48	4.43	4.37	4.30	4.25
4.97½	4.92	4.86	4.80	4.74	4.68	4.62	4.56	4.50	4.45	4.39	4.32	4.27
5.00	4.95	4.89	4.83	4.77	4.71	4.65	4.59	4.53	4.48	4.42	4.35	4.30
5.02½	4.97	4.91	4.85	4.79	4.73	4.67	4.61	4.55	4.50	4.44	4.37	4.32
5.05	5.00	4.94	4.88	4.82	4.76	4.70	4.64	4.58	4.52	4.46	4.39	4.34
5.07½	5.02	4.96	4.90	4.84	4.78	4.72	4.66	4.60	4.54	4.48	4.41	4.36
5.10	5.05	4.98	4.92	4.86	4.80	4.74	4.68	4.62	4.56	4.50	4.43	4.38
5.12½	5.07	5.01	4.95	4.89	4.83	4.76	4.71	4.65	4.59	4.53	4.46	4.40
5.15	5.10	5.04	4.98	4.92	4.85	4.80	4.74	4.68	4.62	4.56	4.49	4.43
5.17½	5.11	5.05	5.00	4.94	4.88	4.82	4.76	4.70	4.64	4.58	4.51	4.45
5.20	5.14	5.08	5.04	4.96	4.90	4.84	4.78	4.72	4.66	4.60	4.53	4.47
5.22½	5.16	5.10	5.06	4.98	4.92	4.86	4.80	4.74	4.68	4.62	4.55	4.49
5.25	5.19	5.12	5.08	5.00	4.94	4.88	4.82	4.76	4.70	4.64	4.57	4.51
5.27½	5.21	5.15	5.11	5.02	4.96	4.90	4.84	4.78	4.72	4.66	4.59	4.53
5.30	5.24	5.18	5.13	5.05	4.98	4.92	4.86	4.80	4.74	4.68	4.61	4.55
5.32½	5.26	5.20	5.15	5.07	5.00	4.94	4.88	4.82	4.76	4.70	4.63	4.57
5.35	5.29	5.22	5.18	5.09	5.02	4.96	4.90	4.84	4.78	4.72	4.65	4.59
5.37½	5.31	5.25	5.20	5.12	5.05	4.99	4.92	4.86	4.80	4.74	4.67	4.61
5.40	5.34	5.27	5.23	5.14	5.07	5.01	4.94	4.88	4.82	4.76	4.69	4.63
5.42½	5.37	5.30	5.25	5.17	5.10	5.03	4.96	4.90	4.84	4.78	4.71	4.65
5.45	5.39	5.32	5.27	5.19	5.12	5.05	4.98	4.92	4.86	4.80	4.73	4.67
5.47½	5.41	5.35	5.30	5.21	5.14	5.07	5.00	4.94	4.88	4.82	4.75	4.69
5.50	5.44	5.38	5.33	5.23	5.16	5.09	5.02	4.96	4.90	4.84	4.77	4.71
5.52½	5.47	5.40	5.35	5.26	5.19	5.12	5.05	4.98	4.92	4.86	4.79	4.73
5.55	5.49	5.42	5.38	5.28	5.21	5.14	5.07	5.00	4.94	4.88	4.81	4.75
5.57½	5.52	5.45	5.40	5.31	5.24	5.17	5.10	5.02	4.96	4.90	4.83	4.77
5.60	5.54	5.47	5.42	5.33	5.26	5.19	5.12	5.04	4.98	4.92	4.85	4.79
5.62½	5.56	5.49	5.44	5.35	5.28	5.21	5.14	5.06	5.00	4.94	4.87	4.81
5.65	5.58	5.52	5.46	5.37	5.29	5.22	5.16	5.08	5.02	4.96	4.89	4.83
5.67½	5.61	5.54	5.48	5.39	5.31	5.24	5.18	5.10	5.04	4.98	4.91	4.85
5.70	5.63	5.56	5.51	5.41	5.33	5.26	5.20	5.12	5.06	5.00	4.93	4.87
5.72½	5.66	5.59	5.54	5.44	5.36	5.29	5.23	5.15	5.08	5.02	4.95	4.89
5.75	5.68	5.62	5.56	5.47	5.39	5.32	5.26	5.18	5.10	5.04	4.97	4.91
5.77½	5.71	5.64	5.57	5.49	5.41	5.34	5.28	5.20	5.12	5.06	4.99	4.93
5.80	5.73	5.65	5.59	5.50	5.42	5.35	5.29	5.22	5.14	5.08	5.01	4.95
5.82½	5.75	5.67	5.62	5.52	5.44	5.37	5.31	5.24	5.16	5.10	5.03	4.97
5.85	5.77	5.70	5.64	5.55	5.46	5.40	5.34	5.26	5.18	5.12	5.05	4.99
5.87½	5.80	5.72	5.67	5.57	5.49	5.42	5.36	5.28	5.20	5.14	5.07	5.00
5.90	5.82	5.75	5.70	5.60	5.52	5.45	5.39	5.31	5.22	5.16	5.08	5.02
5.92½	5.85	5.77	5.72	5.63	5.55	5.48	5.42	5.33	5.24	5.18	5.10	5.04
5.95	5.88	5.80	5.75	5.65	5.57	5.50	5.44	5.36	5.27	5.21	5.12	5.07
5.97½	5.90	5.83	5.78	5.68	5.60	5.53	5.47	5.39	5.30	5.24	5.16	5.09
6.00	5.93	5.86	5.79	5.71	5.63	5.56	5.50	5.42	5.34	5.27	5.20	5.12

TABLE 125. YARDS TO THE POUND OF THROWN SILK BASED ON DRAMS PER 1000 YARDS

Drams per 1000 Yards	Yards per Pound	Drams per 1000 Yards	Yards per Pound	Drams per 1000 Yards	Yards per Pound
1.70	150,588	2.01	127,363	2.76	92,754
1.70	149,708	2.02	126,733	2.77	92,419
1.72	148,837	2.03	126,108	2.78	92,086
1.73	147,977	2.04	125,490	2.70	91,756
1.74	147,126	2.05	124,878	2.80	91,429
1.75	146,286	2.06	124,272	2.81	91,103
1.76	145,455	2.07	123,671	2.82	90,780
1.77	143,820	2.08	123,077	2.83	90,459
1.79	143,017	2.09	122,488	2.84	90,141
1.80	142,222	2.10	121,905	2.85	89,825
1.81	141,436	2.55	100,392	2.86	89,510
1.82	140,659	2.56	100,000	2.87	89,199
1.83	139,891	2.57	99,611	2.88	88,889
1.84	139,130	2.58	99,225	2.89	88,581
1.85	138,378	2.59	98,842	2.90	88,276
1.86	137,634	2.60	98,462	2.91	87,973
1.87	136,898	2.61	98,084	2.92	87,671
1.88	136,170	2.62	97,710	2.93	87,372
1.89	135,450	2.63	97,338	2.94	87,075
1.90	134,737	2.64	96,970	2.95	86,780
1.91	134,031	2.65	96,604	2.96	86,486
1.92	133,333	2.66	96,241	2.97	86,195
1.93	132,642	2.67	95,880	2.98	85,906
1.94	131,959	2.68	95,522	2.99	85,619
1.95	131,282	2.69	95,167	3.00	85,050
1.96	130,612	2.70	94,815	3.02	84,768
1.97	129,949	2.71	94,465	3.03	84,488
1.98	129,293	2.73	93,773	3.04	84,211
1.99	128,643	2.74	93,431	.....	.....
2.00	128,000	2.75	93,091	.....	.....

TABLE 127. DENIER TABLE

Equivalents of Various Deniers in Use in Terms of the Legal Denier Basis

New Legal Denier	Old Milan Denier	Old Turin Denier	Old Lyons Denier	Inter- national Denier	
10.	10.3	9.9	9.9	11.1	The legal denier basis is a skein of silk 450 meters in length weighed by a unit of five centigrams (called denier), or 0.05 of a gram.
2	10.6	10.1	10.1	11.3	
4	10.8	10.3	10.3	11.6	
6	11.	10.5	10.5	11.8	
8	11.2	10.7	10.7	12.	
11.	11.4	10.9	10.9	12.2	The Old Milan denier basis is a skein of silk 476 meters in length weighing 0.0511 of a gram.
2	11.6	11.1	11.1	12.4	
4	11.8	11.3	11.3	12.7	
6	12.	11.5	11.5	12.9	
8	12.2	11.7	11.7	13.1	
12.	12.4	11.9	11.9	13.3	The Old Turin denier basis is a skein of silk 476 meters in length weighing 0.05336 of a gram.
2	12.6	12.1	12.1	13.6	
4	12.8	12.3	12.3	13.8	
6	13.	12.5	12.5	14.	
8	13.2	12.7	12.7	14.2	
13.	13.4	12.9	12.9	14.4	The Old Lyons denier basis is a skein 476 meters long weighing 0.05311 of a gram.
2	13.7	13.1	13.1	14.7	
4	13.9	13.3	13.3	14.9	
6	14.	13.5	13.5	15.1	
8	14.3	13.7	13.7	15.3	
14.	14.5	13.9	13.9	15.6	The New Lyons denier basis is a skein 500 meters long weighing 0.05311 of a gram.
2	14.7	14.1	14.1	15.8	
4	14.9	14.3	14.3	16.	
6	15.1	14.5	14.5	16.2	
8	15.3	14.7	14.7	16.4	
15.	15.5	14.9	14.9	16.7	The International denier basis is a skein 500 meters long weighing 0.05 of a gram.
2	15.7	15.1	15.1	16.9	
4	15.9	15.3	15.3	17.1	
6	16.1	15.5	15.5	17.3	
8	16.3	15.7	15.7	17.6	
16.	16.6	15.9	15.9	17.8	Therefore, 100 legal deniers equal 103.501 Old Milan deniers; or 99.117 Old Turin deniers; or 99.583 Old Lyons deniers; or 111.111 International deniers
2	16.8	16.1	16.1	18.	
4	17.	16.3	16.3	18.2	
6	17.2	16.5	16.5	18.4	
8	17.4	16.6	16.7	18.7	
17.	17.6	16.8	16.9	18.9	To find the equivalent of a 14-Legal denier silk in a 14-Old Turin denier silk, multiply 14 by .99117 = 13.87638.
2	17.8	17.	17.1	19.1	
4	18.	17.2	17.3	19.3	
6	18.2	17.4	17.5	19.6	
8	18.4	17.6	17.7	19.8	
18.	18.6	17.8	17.9	20.	
19.	19.7	18.8	18.9	21.1	
20.	20.7	19.8	19.9	22.2	

BIBLIOGRAPHY

- Adam. *Le cocotier en Afrique*. Paris, 1910.
- Adams. *Rapport sur la sériculture au Japon*.
- Alcan. *Études sur les arts textiles a l'Exposition de 1867*.
- *Traité complet de la filature du coton*. Paris, 1875.
- Allard. *The Fibres of Long Staple Uplands Cottons*. U. S. Bulletin
III. 1907.
- *Crossing in Cotton*. Amer. Breeders' Mag., No. 4, p. 147.
- Allen. *Commercial Organic Analysis*. Vol. 1 and Vol. 3, Part III.
Philadelphia, 1898.
- Allievo. *Le fibre tessile di applicazione industriale*. 1908.
- Alliotta. *Revista critica del genere Gossypium*. Portici, 1903.
- Alworden. *Studien über die Einwirkung von Chlor auf Schafwolle*.
Berlin, 1913.
- Amott. *Silk production in China, India and Europe from the Earliest Times*. London, 1865.
- Anzoux. *Ver à soie*. Paris, 1849.
- Arloz. *La culture du coton à la côte française des Somalis*. Marseilles, 1906.
- Arnaudon. *Sur les soies végétales*. Mon. Scient., 1893.
- Arthus. *Pen pictures of Standard Cotton Grades*. 1919.
- Asbestos Industry. Library of Congress. Div. of Bibliography.
1920.
- Auer. *Ueber die Bastfasern der Moraceen*. Oester. Botan. Zeitsch.,
1903, p. 353.
- *Annuaire de l'industrie linière*. Lille.
- Aufroy. *Expériences sur le rouissage du jute*. Paris, 1904.
- Baine. *History of the Cotton Manufacture in Great Britain*. London, 1835.
- Baker. *Cloth Made from Seaweed*. Cons. Rep., 1910, No. 125.
- Balls. *Botanical Notes on Cotton*. Cairo Scient. Jour., 1909, p. 139.
- *The Cotton Crop of Egypt*. Cairo Scient. Jour., 1908, p. 247.
- Barba. *El Hennequen en Yucatan*. Mexico City, 1895.
- Barham. *Essay upon the Silkworm*. London, 1719.

- Barillé. *Étude sur les Fibres Textiles*. Strassburg, 1868.
- Barker and Priestley. *Wool Carding and Combing*. London, 1919.
- Barret. *L'industrie Cotonnière de Bombay*. 1906.
- Bastoe and Appleyard. *Chemie der Tussah*. *Chemiker Zeit.*, Vol. 12, p. 209.
- Baudoin. *Sur le coton au Cambodge*. 1905.
- Bavier. *Japans Seidenzucht*. Zurich, 1874.
- Beaumont. *Wool Substitutes*. London, 1922.
- Beauverie. *Les Textiles Végétaux*. Paris, 1913.
- Becker. *Die Kunstseide*. Halle, 1912.
- Beech. *Dyeing of Cotton Fabrics*, pp. 1-22. London, 1901.
- *Dyeing of Woolen Fabrics*, pp. 1-14. London, 1902.
- Behrens. *Anleitung zur mikrochemischen Analyse der wichtigsten organischen Faserstoffe*. Hamburg, 1908.
- Beltzer. *Industries des Poils et Fourrures Cheveux*. Paris, 1912.
- and Persoz. *Les Matières Cellulosiques*. Paris, 1911.
- Benedict and Ulzer. *Analyse der Fette und Wachsarten*. Berlin, 1903.
- Benoit. *Étude sur la ramie*. Paris, 1901.
- Berard. *Le Chanvre de Manille*. Paris, 1902.
- Bernardin. *Nomenclature nouvelle des 550 fibres textiles*. Ghent, 1872.
- Berthold. *Ueber die mikroskop. merkmale der wichstigen Pflanzenfasern*. 1888.
- Berthollet. *Éléments de l'art de la teinture*. Paris, 1804.
- Betti. *Dissertazione istorica la seta*. Verona, 1765.
- Biesiadecky. *Artikel Haut, Haare und Nagel in Stricker's Handbuch der Lehre von der Geweben*. Leipsig, 1871.
- Bischoff. *Geschichte der Färberei*.
- Blair. *Russlands Seidenbau*. St. Petersburg, 1886.
- Blanc. *Étude sur la sécrétion de la soie*. *Bulletin Laboratory*. Lyon, 1890.
- Bocken. *Fibers and Fiber production*. New Zealand Dept. of Agric., Bull. 45.
- Bohm. *Die Schafzucht*.
- Bolley. *Beiträge zur Theorie de Färberei*.
- *Elastizität der Seide*. *Centralblatt Textilindustrie*, 1884, p. 495.
- *Mikroskopische und chem. Untersuchungen der Tussah*. *Centralblatt Textilindustrie*, 1885, p. 829.
- *Untersuchung über die Yamamayseide*. *Polyt. Zeits.*, 1869, p. 142.
- *Zur Genesis der Seide*. *Dingl. Polyt. Jour.*, 1865.
- und Schosh. *Ueber die Seiden*. *Dingl. Polyt. Jour.*, 1870, p. 196.

- Bonnetat. *Les plantes textiles*. Hachette, 1907.
- Borain. *La culture du coton*. Brussels, 1875.
- Bothier. *La ramie*. Paris, 1902.
- Bottler. *Die animalischen Faserstoffe*. Leipzig, 1902.
- *Die vegetabilischen Faserstoffe*. Leipzig, 1900.
- Bouce and Grothe. *Ramie, China-grass und Nesselfaser*. Berlin, 1884.
- Bowman. *The Structure of the Cotton Fiber*. London, 1908.
- *The Structure of the Wool Fiber*. London, 1908.
- Boyé. *Suppression due rouissage, du lin et due chanvre*. Paris, 1862.
- Bradbury. *Calculations in Yarns and Fabrics*. Belfast, 1906.
- Bray. *La ramie*. Paris, 1879.
- Brenier. *La culture due cotonnier dans les colonies françaises*, 1903.
- Brinkmeier. *Der Hanfè*. Ilmenau, 1886.
- Brooks. *Cotton Manufacturing*. Blackburn, 1888.
- *Handbook for Cotton Manufacturing Students*. London, 1889.
- Browne. *Trichologia Mammalium*. Philadelphia, 1853.
- Bruck. *Tropenpflanzen*, Vol. 13, p. 387.
- Brunel. *Le cotan en Algerie*. 1910.
- Buchoz. *Dissertation sur le lin de Sibirie*. 1789.
- Burgenstein. *Ueber Pflanzenfasern* (in *Ver. Zur. Verbreit. Naturw. Kenntnisse*, Vol. 19, p. 245).
- Burkett. *Cotton*. New York, 1907.
- and Hamilton. *Die Baumwolle*.
- Butterworth. *Cotton and its Treatment*. Manchester, 1881.
- Cadoret. *Die kunstliche Seide*. Crefeld, 1894.
- Campbell. *A Treatise on the Cultivation of Flax and Hemp*. Sydney, 1868.
- Capus. *Le cotonnier en Indo-Chine*. 1906.
- Carter. *The Bleaching, Dyeing and Finishing of Flax, Hemp and Jute*. London, 1911.
- *Ramie and China Grass*. London, 1910.
- *Cordage Fibers*. London, 1909.
- Champion. *Industries de l'empire Chinois*. Paris, 1809.
- Chaplet and Rousset. *Les succédanés de la soie*. Paris, 1909.
- Charles-Roux. *La production du coton en Egypte*. Paris, 1909.
- Charpentier. *Les textiles*; *Ency. Chimique*. Paris, 1890.
- Chérot. *Études sur la culture du lin*. 1845.
- Cheney Brothers. *The Story of Silk*. New York, 1916.
- Christy. *New Commercial Plants and Drugs*. 1882.
- Cirkel. *Asbestos*. Ottawa, 1905.
- *Chrysotile Asbestos*. Ottawa, 1910.
- Clark. *Practical Methods in Microscopy*. Boston, 1900.

- Claveries. *Anatomie des plantes textiles exotiques*. Marseilles, 1909.
- Cobb. Tests on Cotton. U. S. Dept. Agric., Bulletin 62.
- Manufacturing Industries, Silk.
- Colerus. *De Bombyce*. Giessen, 1665.
- Combe. Summary of the Origin and Processes of Linen Manufacture. Belfast, 1868.
- Comstock. A Practical Treatise on the Culture of Silk in the United States. Hertford, 1836.
- Conquist. *Das Ganze der Asbest-Verarbeitung*. Berlin, 1913.
- Conter. Cultivation of Sisal in Hawaii. Honolulu, 1902.
- Cook. Origin of Hindi Cotton. Bur. Plant Ind., Circular 42.
- Corda. *Die webbaren Fasern Organischen Ursprungs* Mikrosk. Untersucht.
- Cordemoy. *Le coton en Egypte*. 1897.
- Cornalia. *Bombyce del selso*. Mem. Inst. Lombardo, 1856.
- Correa. *Plantas fibrosas da restinga do estado do Rio de Janeiro*, 1910.
- Cramer. *Die Bestandteile der Rohseide*. Dingl. Polyt. Jour., 1865.
- *Drei Gerichtliche mikroskopische Expertisen betreffend Textilfasern*. Zurich, 1881.
- *Untersuchung der Seide*. Jour. Prakt. Chem., Vol. 96.
- Crawford. *Irish Linen*. 1910.
- Cross and Bevan. *Cellulose*. London, 1895.
- *Researches on Cellulose, 1895 to 1900*. London, 1901.
- *Researches on Cellulose, 1900 to 1905*. London, 1906.
- *Researches on Cellulose, 1905 to 1910*. London, 1912.
- *Paper Making*, pp. 1-110. London, 1900.
- *Bevan and King. Report on Indian Fibres*. London, 1887.
- Crum. *On the Cotton Fiber*. 1853.
- Cuniasse et Zwillling. *Essais du commerce; matières textiles*, pp. 225-232. Paris, 1901.
- Dahl. *Seidenspinne und Spinnenseide*.
- Dana. *Cotton from Seed to Loom*. New York, 1878.
- Dangers. *Neue Gespinnstpflanzen*. Landw. Zeit., 1880, No. 4.
- Dannerth. *Methods of Textile Chemistry*. New York, 1908.
- Danzer. *Les industries textiles a l'Exposition de 1889*. Paris, 1889.
- David. *Handbuch der Seidenfärberei*. Aarau, 1885.
- Davidson. *La ramie à Formose*. Paris, 1903.
- *La fibre d'ananas de Formose*. Paris, 1903.
- Davis, Dreyfus and Holland. *Sizing and Mildew in Cotton Goods*. Manchester, 1883.
- Delamer. *Flax and Hemp*. London, 1854.
- Delden. *Studien über die indische Juteindustrie*. Leipzig, 1915.

- Demoor. *Traité de la culture du lin et des differents modes de rouissage*. Brussels, 1855.
- Dennet. *Vegetable Fibers*. Brighton, 1875.
- Deschamps. *Le coton*. Paris, 1885.
- Desieyez. *L'abaca aux îles Philippines*. Paris, 1902.
- Deutscher Färber-Kalender. Wittenberg, 1912-1918.
- Dewey. *Cultivation of Hemp in the United States*. U. S. Dept. of Agric., Circ. 57.
- *The Hemp Industry in the United States*. U. S. Dept. Agric. Year Book, 1901.
- *Principal Commercial Plant Fibers*. U. S. Dept. Agric. Year Book, 1903.
- Dewhurst. *A Familiar Treatise on the Natural History and Management of the Common Silk-Worm*. London, 1839.
- Devilliers. *Manuel de la soierie*. Paris, 1839.
- D'Homergue. *The Silk Culturist's Manual*. Philadelphia, 1839.
- Dickson. *Fiber Plants of India*, 1865.
- Dodge. *Report on Flax, Hemp, Ramie and Jute*. U. S. Dept. of Agric., Report No. 1.
- *Report on Sisal Hemp Culture*. U. S. Dept. of Agric., Report No. 3.
- *Flax Culture for Fiber in the United States*. U. S. Dept. Agric., Report No. 4.
- *Report on Leaf Fibers*. U. S. Dept. Agric., Report No. 5.
- *Report on Cultivation of Ramie in the U. S.* U. S. Dept. Agric., Report No. 7.
- *Descriptive Catalogue of the Useful Fiber Plants of the World*. U. S. Dept. of Agric., Report No. 9, 1897.
- *Report on Flax Culture*. U. S. Dept. of Agric., Report No. 10, 1898.
- Donath and Margoscher. *Das Wollfett*. Stuttgart, 1901.
- Donnell. *History of Cotton*. New York, 1872.
- Drabble. *African Fibrous Plants*. Jour. Inst. Commercial Research in Tropics, 1907, p. 133.
- Draper Co. *Textile Tests for Cotton Manufacturers*. Milford, 1917.
- Dubois. *Die Absonderung der Seidensubstanz*. Comptes. rend., Vol. III, p. 482.
- *Ueber den natürlichen Faserstoff der Seide*. Comptes. rend., Vol. III, p. 434.
- Duhamel du Monceau. *Traité de la Corderie*, 1769.
- Dupont. *La filature du coton*. Paris, 1881.
- Duran. *Raw Silk: a Practical Handbook for the Buyer*. New York, 1913.
- Durand. *Étude sur le chanvre et de lin*. Paris, 1898.

- Duseigneur-Kleber. *Le Cocon de soie*. Paris, 1875.
 Dunstan. *Le coton en Asie-Mineure*. 1908.
- Earle and Dean. *Classification and Grading of Cotton*. U. S. Dept. Agric., Bull. 591.
 Ebert. *Deutsche Faserstoff-Kalender*.
 Eble. *Die Lehre von der Haaren*; 2 vols. Vienna, 1831.
 Editors of the "Dyer and Calico Printer"; *Mercerisation*. London, 1903.
 Edmondson. *Universal Tables of Textile Structure*. London, 1886.
 Einöhrli. *Textile Handelskunde*. 1906.
 Ellison. *Handbuch du Baumwollculture*. Bremen, 1881.
 Engle. *Ueber das Wachsen abgeschnittener Haare*. 1856.
 Erdl. *Vergleichende Darstellung des inneren Baues der Haare*, 1841.
- Farmer. *La culture du cotonnier*. Paris, 1901.
 Favier. *Note industrielle sur la ramie*. Avignon, 1882.
 — *Nouvelle histoire de la ramie*. Paris, 1886.
 — *The Textile Nettles*. London, 1882.
 Favre. *La ramie*. Tunis, 1884.
 Ferrage. *Culture du lin*. Toulouse, 1887.
 Fiedler. *Die Materialien der Textil-industrie*. Hanover, 1909.
 Flatters. *The Cotton Plant*. London, 1906.
 Fleming. *Manufacture of Jute*. *Sciences annales*, p. 3928.
 Fletcher. *Origin of Egyptian Cotton*. Cairo, 1908.
 Focke. *Mikrosk. Untersuch. der bekanntesten Gespinnstfasern der Shoddywolle, etc.* Archiv. du Pharmacies, 1886.
 Foltzer. *Fabrication de la soie artificielle*. Paris, 1903-1905.
 de Francheville. *Le Bombyx*. Berlin, 1754.
 Francke. *Die neuere Entwicklung der Textil-industrie in Deutschland*, 1885.
 Fremey. *La ramie*. Paris, 1884.
 Frey. *Das Mikroskop für Aertze, etc.*
 Fritsch. *Culture des plantes oleagineuses et textiles*. Paris, 1902.
 Frost. *Flachsbau und Industrie in Holland, Belgien und Frankreich*. Berlin, 1909.
- Gaidukov. *Ueber die Anwendung des Ultramikroskops nach Seidentopf*. *Zeitschrift angew. Chem.*, 1908, p. 393.
 Gammie. *The Indian Cottons*. Mem. Bot. Series, Vol. 2, No. 2.
 Ganeval. *Le coton*. Lyons, 1881.
 Ganswindt. *Die Technologie der Appretur*. Vienna, 1907.
 Gard. *Le crin végétal*. Bordeaux, 1903.
 Gardner. *Mercerisation und Appretur*. Berlin, 1912.

- Gardner, W. Wool Dyeing; Part I, pp. 7-19. Philadelphia, 1896.
- de Gasparin. Histoire de l'introduction du ver a soie.
- Geldard. Handbook on Cotton Manufacture. New York, 1867.
- Geohegan. Silk in India. Calcutta.
- Georgievics. Chemische Technologie der Gespinnstfasern; 2 vols. Leipzig, 1907 and 1908.
- Chemical Technology of the Textile Fibers. Trans. Salter. London, 1902.
- Gibbs. New Zealand Flax. London, 1865.
- Gilson. La soie. La Cellule, Vol. 6, 1890.
- Giraud. Les origines de la soie. Lyons, 1883.
- Girola. Las plantas textiles de la Republica Argentina. Buenos Aires, 1903.
- Glafey. Die Rohstoffe der Textil-industrie. Leipzig, 1910.
- Gliddon. Memoir on the Cotton of Egypt. London, 1841.
- Gnehm. Taschenbuch für die Färberei und Farbenfabriken: "Gespinnstfasern." pp. 1-17. Berlin, 1902.
- Gotthard. Die Seidenraupe. Erfurt.
- Goulding. Cotton and other Vegetable Fibers. London, 1917.
- Graugnard. La ramie. Marseilles, 1878.
- Greef. Mitth. über die Lage der Halbseidenindustrie. Vienna, 1885.
- Green. Notes on Certain Silkweeds. Coulter's Bot. Gaz., 1880, p. 64.
- Greengrass. Fibres d'aloës. Paris, 1903.
- Greshoff. La pretendue fibre d'ananas de Java. Paris, 1906.
- Grothe. Gespinnstfasern aus Agaven. Dingl. Polyt. Jour., 1880, p. 157.
- "Textile Industrie" in Muspratt's Chemie, Vol. 5.
- Technologie der Gespinnstfasern; Vollständiges Handbuch der Spinnerei. Berlin, 1876 and 1882.
- Guerin-Meneville. The Ailanthus Silkworm. London, 1862.
- Gurlt. Vergleichende Untersuchungen über die Haut. Berlin, 1844.
- Gürtler. Textilindustrie; 2 vols. Leipzig, 1908.
- Haberlandt. Die Seidenspinnen. Vienna, 1871.
- Habler. Mikroskopische Diagnostik der Baumwollarten.
- Halphen. La pratique des essais commerciaux et industriels, matières organiques; textiles et tissus; pp. 326-342. Paris, 1893.
- Hamon. Culture de lin en Bretagne.
- Hanausek. Lehrbuch der technischen Mikroskopie. Stuttgart, 1900.
- Die Raphiafaser. Berichte, 1885, p. 152.
- Ueber Merzerisierung. Dingl. Polyt. Jour., 1898, p. 180.
- und Neberki. Mikroskopie von Pelzhaaren. Jahresbericht der Wiener Handelsakademie, 1884.

- Hanmann. Das Ganze des Seidenbaues. Ilmenau, 1829.
- Hannan. Textile Fibres of Commerce. London, 1902.
- Hassack. Beiträge zur Kenntniss der künstlichen Seiden. Oest. Chem. Zeit., 1900, No. 10-12.
- Ramie. Vienna, 1890.
- Die Unterscheidung der Gewebefasern. Verbreitung naturw. Kenntnisse in Wien, Vol. 2, p. 55.
- Ueber Herstellung und Eigenschaften der künstlichen Seiden. Oest. Chem. Zeit., 1900, No. 1.
- Haussner. Vorlesungen über Mechanische Technologie der Faserstoffe.
- Hauttefeuille. Étude sur jute dans l'Inde. Paris, 1904.
- Fibres de bananier. Paris, 1908.
- L'agave textile. Paris, 1907.
- Havick. Résistance des fibres. Jaart Dept. Landt. Nederland. Indie, 1908.
- Hazzi. A Treatise on the Culture of Silk in Germany. Washington, 1828.
- Lehrbuch des Seidenbaues. München, 1826.
- Hector. Le Phormium, 1889.
- Heermann. Dyer's Materials: "Textile Fibres"; pp. 16-24. Trans. Wright. London, 1900.
- Mechanisch- und Physikalisch-, technische Textiluntersuchungen. Berlin, 1912.
- Untersuchungsmethoden der Textilchemie. Berlin, 1902.
- Hehn. Kulturpflanzen und Haustiere aus Asien. Berlin, 1874.
- Heinde und Rasser. Handbuch der Papier Textil-industrie.
- Heizmann. Die Baumwolle.
- Hellott. Théorie chimique de la teinture de l'étoffe, in Mem. de l'Acad. Française. 1740.
- Helm. Entstehung der Seide. Zeit Zoologie. 1876, p. 434.
- Henri. Die Seide. Dresden, 1897.
- Henry. Détermination de la valeur commerciale des fibres de coton. 1902.
- Herzer. Gesammelte Nachrichten und Selbsterfahrung durch Aus-suchung deutscher Seiden und Wollgewäsche. Regensburg, 1795.
- Herzfeld. Die technische Prüfung der Garne und Gewebe. Vienna, 1896.
- Das Färben und Bleichen, etc.; 2 vols. Berlin, 1890 and 1905.
- Technical Testing of Yarns and Fabrics. London, 1898.
- Herzinger. Die Technik der Mercerisation. Reuss, 1911.
- Herzog. Die Flachsfaser in mikroskopischer und chemischer Beziehung.

- Herzog. Mikrophotographischer Atlas der technisch wichtigen Faserstoffe. Munich, 1908.
- Ueber das optische Verhalten der Gelatineseide. Oest. Chem. Zeit., 1906, No. 12.
- Die Unterscheidung von Baumwolle und Leinen, 1908.
- Beiträge zur Kenntniss des Flachsfaser. Chem. Zeit., 1898, p. 310.
- Zur Kenntniss der Dopplebrechung der Baumwollfaser. Koll. Zeit., Vol. 5, No. 5.
- Zur Kenntniss der neuen Azetatseide. Chem. Zeit., 1910, No. 40.
- Die Unterscheidung der natürlichen und künstlichen Seiden. Dresden, 1910.
- Higgins. On the Microscopic Character of Cotton. Proc. Lib. and Phil. Soc. of Liverpool, 1872.
- Hilgard. La ramie en California. Paris, 1903.
- Hitier. Les plantes industrielles. Encycl. Wery.
- Hofmann. Traité pratique de la fabrication du papier. 1876.
- Handbuch der fränkischen Seidenerzeugung. Würzburg, 1839.
- Observationes circa Bombyces. Tübingen, 1757.
- Höhnel. Die Unterscheidung der pflanzlichen Textilfasern. Dingl. Polyt. Jour., Vol. 246, p. 465.
- Ueber die Bildung der Seide. Warenkunde u. Technol., Parts III and V.
- Beiträge zur technischen Rohstofflehre. Dingl. Polyt. Jour., Vol. 252.
- Ueber den Bau und die Abstammung der Tillandsiafaser. Dingl. Polyt. Jour., Vol. 234, p. 407.
- Die Mikroskopie der technisch verwendeten Faserstoffe. Leipzig, 1887 and 1905.
- Ueber die Kollodiumseide. Tech. Gew. Mus. in Vienna, 1890.
- Hooker. Jute. Phar. Jour., 1850, p. 359.
- Hooper. Silk, its Production and Manufacture. London, 1911.
- Hort. Deutsche Seidenkultur. Wollengewerbe, Vol. 20, p. 209.
- Howard. Studies in Indian Fiber Plants. Dept. Agric. India, 1911.
- Hoyer. Das Papier, seine Beschaffenheit und deren Prüfung. Munich, 1881.
- L'extraction du coir. Paris, 1907.
- Hübner. Bleaching and Dyeing of Vegetable Fibrous Substances. London, 1912.
- Hülse. Die Technik der Baumwollspinnerei. Stuttgart, 1863.
- Hummel. Dyeing of the Textile Fibres. London, 1896.
- Hyde. The Science of Cotton Spinning. Manchester.

Ichenhauser. *Kunstseide.*

Imperial Institute. *Fibers.* Report No. 58.

International Textbook Co. *Burring and Carbonising.* Scranton, 1910.

Janke. *Wool Production,* 1864.

Jackson. *Ramie. Agric. Gaz. Wales,* Vol. 18, p. 744.

de Janville. *Atlas des plantes utiles des pays chauds.* 1902.

Jeziarski. *Jedwabnictwo polskie.* Warsaw, 1838.

Joclét. *Chemische Bearbeitung der Schafwolle.* Leipzig, 1902.

Johannsen. *Die Faserstoffe.*

— *Faserstoffe. Die Technik im Zwanzigsten Jahrhundert,* Vol. I, pp. 353-397.

Jones. *Asbestos.* London, 1897.

Joseph. *Asbestos.* Tucson, 1916.

Kappf. *Ueber Wolle, Baumwolle, etc.* Leipzig, 1960.

Karmarsh. *Technisches Wörterbuch; Artikel "Baumwoll" und "Gespinnstfasern."* 1876.

Karpeles. *La ramie en Indo-Chine.* Paris, 1906.

Keer. *Report on Cultivation and Trade of Jute.* Calcutta, 1877.

Kenrick. *The American Silk-growers Guide.* Boston, 1835.

Kérébel. *De l'examen des fibres textiles végétales dans la marine,* 1890.

Kestner. *Die Yamaseide. Deutsche Gewerbeztg.,* 1866, p. 1260.

Kew Bulletin. *Vegetable Fibers. Series 2.*

Kiellmeyer. *Die Entwicklung der Färberei, Bleicherei, Druckerei.*

Dingl. Polytechn. Jour., Vol. 234, p. 63.

— *Der Färberlehrling in Chemie-Examen.* Wittenburg, 1910.

Kirkwood. *Some Mexican Fiber Plants.* *Plant World,* 1909, p. 25.

Knecht, Rawson and Loewenthal. *Manual of Dyeing.* London, 1910.

Knidt. *Industrie linière.* Brussels, 1852.

Kodolanyi. *Die Kultur und Zubereitung des Flachses.*

Kolliker. *Handbuch der Gewebelehre.*

Krutzsch. *Beiträge zur Förderung des Seidenbaues.* Leipzig, 1838.

Kuhn. *Die Baumwolle.* Leipzig, 1892.

Kuhnert. *Der Flachs.* Berlin, 1898.

Kuhnnow. *Flachsanbau und Aufbereitung.*

Kurrer. *Geschichte der Zeugdruckerei.* Nürnberg, 1844.

Labrousche. *Le chanvre de Manille.* Paris, 1906.

Lacroix. *Grand dictionnaire industriel.* Paris, 1888.

Ladureau. *Culture du lin.* Lille, 1878.

Lafar. *Technical Mycology,* Vol. 1. London, 1898.

- Laliers. *Le coton*, 1908.
- Langer. *Flachsbau und Flachsbereitung*. Vienna, 1893.
- Lardner. *Cabinet Cyclopedia, Silk Manufacture*. London, 1831.
- Lasteyrie. *Du cotonnier et de sa cultur*. Paris, 1808.
- Lauber. *Praktisches Handbuch des Zeugdrucks*; 3 vols. Leipzig, 1901.
- Laurent de l'Arbousset. *On Silk and the Silkworm*. Leek, 1905.
- Leavitt. *The Culture and Manufacture of Flax and Hemp*. Rep. Com. Pats. Washington, 1862.
- Leblanc. *Le ouatier du Cambodge*. Paris, 1903.
- Le Blanc. *Système complet de la filature du coton*. Paris, 1828.
- Lecointre. *Traité de l'analyse des étoffes*. Paris, 1905.
- Lecomte. *Culture du jute*. Paris, 1897.
- *La ramie* (Rev. gén. sciences). Paris, 1890.
- *Textiles vegetaux*. Paris.
- Lederlin. *Blanchiment, teinture, impression, apprêts*. Paris, 1923.
- Lee. *The Vegetable Lamb of Tartary*. London, 1887.
- Lefroy and Ghosh. *Eri Silk*. Dept. Agric. India, Entomological Series, Vol. 4, No. 1.
- Legatt. *Theory and Practice of Jute*. Dundee, 1893.
- Leger. *La ramie*. Lyons, 1881.
- Leigh. *The Science of Modern Cotton Spinning*. Manchester, 1877.
- Lenz. *Chemische Analyse der Seidenraupen*. Ann. Landw. Wochbl., 1868.
- *Zur Unterscheidung der Jutefaser*. Zeit. anal. Chem., 1890, p. 133.
- Lewis. *Physical Testing of Cotton Yarns*. U. S. Bur. Standards, paper 19.
- Leydig. *Lehrbuch der Histologie*.
- L'Homme. *Laine et coton*. Paris, 1881.
- Linsbauer. *Mikroskopisch-technische Untersuchungen über Torffaser und deren Produkte*. Dingl. Polyt. Jour., Vol. 315, p. 437.
- Löbner (H). *Studien und Forschungen über Wolle*. Grünberg, 1898.
- Locke. *Observations on the Production of Silk*. London, 1766.
- Löhner (O). *Carbonisation der Wolle*. Grünberg, 1891.
- Luccock. *The Nature and Properties of Wool*. Leeds, 1805.
- Lunge. *Chemische technische Untersuchungsmethoden*, Vol. 3, pp. 1026-1056. Berlin, 1900.
- Lyman. *Cotton culture*. New York, 1865.
- McBride. *Chemistry of Cotton*. U. S. Dept. Agric., Bull. No. 33.
- McMurtrie. *Report upon the Examination of Wool Fibers*. U. S. Dept. of Agric., 1886.

- Macquer. *Art de la teinture*. Paris, 1763.
- Maireaux. *Les agaves textiles du Mexique*. Paris, 1904.
- Mallet. *Cotton: the Chemical, etc. Conditions of its Culture*. London, 1862.
- Malpighi. *Discussatio epistolica de Bombyce*. London, 1669.
- Manget. *Tableaux synoptiques pour l'examen des tissus*. 1902.
- Marcandier. *Traité du chanvre*. Paris, 1795.
- Marchadier. *Le rouissage du chanvre*. Le Mans, 1911.
- Margosches. *Die Viscose*. Leipzig, 1906.
- Marquart. *Der Hanfbau*. Berlin, 1919.
- Marsden. *Cotton Spinning*. London, 1888.
- Massot. *Zur Kenntniss einiger Erzeugnisse der Kuntseiden-industrie*. Chem. Zeit., 1906.
- *Zur Kenntniss neuer Textilfaserstoffe*. Färber-Zeit., 1907. No. 10-13.
- *Appretur und Schlichte-Analyse*. Berlin, 1911.
- Masters. *On a New Species of Gossypium*. Jour. Linn. Soc. London, 1882.
- Matthews. *Application of Dyestuffs*. New York, 1920.
- *Bleaching and Related Processes*. New York, 1921.
- *Laboratory Manual of Dyeing and Textile Chemistry*. New York, 1908.
- *The Textile Fibers*. New York, 1913, 1923.
- Mène. *Analysen gelber Rohseiden*. Comptes rend., 1869, p. 69.
- Mercandier. *Traité due chanvre*. Paris, 1795.
- Merrill. *The Non-Metallic Minerals (for Asbestos)*. New York, 1904.
- Meyer. *Ueber die Verarbeitung des Hanfes und Flachses in ungeroteten zustande durch Maschinen*. Hanover, 1877.
- Michotte. *Traite scientifique et industriel des plantes textiles*.
- Miller. *Alte und neue Farbstoffe*; Augsburgs Allgem. Zeitung., 1885.
- Mitchell and Prideaux. *Fibres Used in Textile and Allied Industries*. London, 1910.
- Moerman. *La Ramie*. Ghent, 1871.
- Mölsch. *Neue Methode zur Untersuchung der Thierfasern und Pflanzenfasern*. Dingl. Polyt. Jour., Vol. 261, p. 135.
- Möller. *Waarenkunde*. Vienna, 1879.
- Monie. *The Cotton Fibre*. Manchester, 1800.
- Moore (A. S.). *Linen from the Raw Material to the Finished Product*. London, 1914.
- *Synopsis of Asiatic Silk Moths*. London, 1859.
- Morand. *La fabrique Lyonnaise de soieries*, 1789, 1889.
- Moreau. *La ramie*. Libr. Horticole, Paris.

- Morris. Commercial Fibres. Cantor Lectures of, Vol. 5.
 — Fiber Plants of Jamaica. Inst. of Jamaica.
 — The Sisal Industry. Colonial Reports No. 5.
 Moyret. Microscopical Examination of Dyed Silk. The Chemical Review, 1882.
 Mucke. Der Baumwollen-Baum, Kapok. Der Pflanzen, Vol. 4, p. 19.
 Mulder. Analyse der Seide. Poggendorff's Annalen, Vol. 37, p. 594.
 Müller (E.). Anleitung zur Ansführung textil-chemischer Untersuchungen. Vienna, 1904.
 — Handbuch der Spinnerei.
 Müller (H.). Die Pflanzenfaser in Hofmann's Berichte. Braunschweig, 1877.
 Mundorf. Die Appretur der Woll- und Halbwollgewebe. Leipzig, 1912.
 Murray. The Natural History of the Silkworm. London, 1838.
 Nathusiun-Königsborn, Das Wollhaar des Schafes in histologischen und technischen Beziehung. Berlin, 1866.
 Netz. Anleitung zur Kultur Seidenraupen. Darmstadt, 1840.
 Niers. Die Baumwollspinnerei. Wiemar, 1885.
 Nunn. Zapupa Fiber Plant. Kew Bull. London, 1907.
 Oelsner. Die Webmaterialen-Kunde. Altona, 1881.
 Oesterreichs. Wollen- und Leinenindustrie.
 Oger. Traité élémentaire de la filature du coton. Mülhausen, 1839.
 O'Neill. A Dictionary of Calico Printing and Dyeing. London, 1862.
 — Experiments and Observations on Cotton. London, 1865.
 — On an Apparatus for Measuring Tensile Strength of Fibers. London, 1865.
 Onekaki-Morikuni. L'art d'élever les vers à soie au Japon.
 Oppel. Die Baumwolle. Leipzig, 1902.
 Orschatz. Traité sur la constitutions des fibres textiles et microscopique de la teinture.
 — Ueber den Bau der wichtigstigen verwendbaren Faserstoffe. Polyt. Centralblatt, p. 1279, 1848.
 Ott. Historisches über die Seidenzucht in Amerika. Wiecks Gewerbeztg., 1870.
 Parent-Duchatelet. Le rouissage du chanvre. Paris, 1832.
 Pariset. Les industries de la soie. Lyons, 1890.
 — Histoire de la soie. Paris, 1862.
 Parlatore. Le specie dei cotoni. Florence, 1866.
 Passon. Die Kultur der Baumwollstande. Stuttgart, 1910.
 Pearsall. On the Chemical Preparation of Flax. Leeds, 1853.
 Pelet-Jolivet. Die Theorie des Färbe Prozesses. Dresden, 1910.

- Peligot. *Chemische und Physiologische Betrachtung der Seidenraupen.* Comptes rend., Vol. 34, p. 33.
- Pelouze. *Exposé complet de la culture du coton aux Antilles.* Paris, 1838.
- Perrot. *Des produits utiles des Bombax.* Paris, 1911.
- Persoz. *Le conditionnement de la soie.* Paris, 1887.
- *Essai des matières textiles.* Paris, 1899.
- *Chemische Untersuchung der Seide.* Moniteur scient., Vol. 1, p. 597.
- *Traité théorique et pratique de l'impression des tissus.* Paris, 1846.
- Pfuhl. *Die Jute und ihre Verarbeitung.* Dresden, 1888.
- *Forstschritte in der Flachsgewinnung.*
- *Physikalische Eigenschaften der Jute.* Berlin, 1888.
- *Papierstoffgarne.* Riga, 1904.
- Piest. *Die Zellulose.* Stuttgart, 1910.
- Pinagel. *Die Mikrophotographische Messung und Untersuchung des Wollhaares,* Aachen. 1899.
- Polleyn. *Dressings and Finishings for Textile Fabrics.* Trans. Salter. London, 1911.
- Porter. *A Treatise on Silk Manufacture.* London, 1830.
- Posselt. *Structur of Fibers, Yarns and Fabrics.* Philadelphia, 1891.
- Pray. *The Cotton Fiber.* Jour. Franklin Inst., Vol. 1, No. 7.
- Pullein. *The Culture of Silk.* London, 1758.
- Quatrefages. *Essai sur l'histoire de la sériculture.* Paris, 1860.
- Quatremere-Disjoulval. *Essais sur les caractères qui distinguent les cotons de diverses parties du monde.* Paris, 1784.
- Raulin. *Chemie der Maulbeer und Eichenseide.* Moniteur des soies, 1890, p. 1445.
- Rawson, Gardner and Laycock. *Dictionary of Dyes, Mordants, etc., articles relating to Textile Fibers.* London, 1901.
- Reichenbach. *Ueber Seidenraupenzucht in China.*
- Reiser and Spennrath. *Handbuch der Weberei.* Berlin, 1885.
- Reisseck. *Die Fasergewerbe des Leines, etc.* Vienna, 1852.
- Remec. *Über die Spezifische Doppelbrechung der Pflanzenfaser.* Vienna, 1901.
- Renouard. *Études sur la culture, le rouissage du lin.* Paris, 1880.
- *Distinction du lin et du chanvre.* Lille, 1875.
- *Études sur le travail des lins, chanvres, jutes.* Lille, 1876.
- *Les arts textiles.*
- *Les fibres textiles des pays tropicaux.* Lille, 1882.
- *Histoire de l'industrie linière.* Paris, 1879.

- Reybaud. *Le coton*. Paris, 1863.
- Reynaud. *Les vers à soie*. Paris, 1812.
- Richard. *Die Gewinnung der Gespinnstfasern*. Brunswick, 1881.
- Riviere. *L'Eriodendron anfractuosum*. Algeria, 1875.
- *La ramie*. Algeria, 1888.
- Robinet. *La sécrétion de la soie*, Amer. Soc. Agric., 1844.
- Roell. *Der Asbest*. Breslau, 1914.
- Roessler-Lade. *Die Nessel eine Gespinnstpflanze*. Ilmenau, 1878.
- Rohde. *Beiträge zur Kenntniss der Wollhaaren*. Eldenaer Archiv., 1856, 1857.
- Romen. *Die Bleicherei, Färberei und Appretur der Baumwollwaren, etc.* Berlin, 1879.
- Rondot. *L'art de la soie*. Paris, 1885.
- *L'industrie de la soie en France*. Lyons, 1894.
- Rosa. *Histoire de la culture des vers a soie*. Jour. de l'agric., 1870.
- Rostaing et Fleury. *Precis du sert. vegetaux propres a la fabrication de la cellulose et du papier*. Paris, 1904.
- *Indian Fibers for Textile Fabrics*. London, 1854.
- Runge. *Farbenchemie*. Berlin, 1834.
- Sadtler. *Handbook of Industrial Organic Chemistry*. Philadelphia, 1922.
- Saito. *Plant-fibers used in the Arts and Manufactures*. Tokio, 1903.
- Saladin. *La filature du coton*. Paris.
- Sansone. *Dyeing Wool, Silk, Cotton, etc.*, Vol. 1, pp. 18-32. London, 1888.
- *Printing of Cotton Fabrics*, pp. 53-73. London, 1901.
- Savorgnan. *Cultivazione ed industrie delle piante tessili*. Milan, 1890.
- Sawyer. *Culture d'ananas pour le fibre*. Paris, 1904.
- Schacht. *Die Prüfung der in Handel vorkommenden Gewebe*. Berlin, 1853.
- Schacorow. *Gewinnung, Verarbeitung und Absatz der Seide*. St. Petersburg, 1890.
- *Mikroskopische Untersuchungen der Textilrohstoffe*. Berlin, 1885.
- Schatz. *Der Torf als Spinn- und Webstoff*. Leipzig, 1911.
- Schick. *Der Textilchemiker*. Reuss, 1910.
- Schiller. *Optische Untersuch. von Bastfasern*. Vienna, 1906.
- Schlesinger. *Examen microscopique et microchemique des fibres Textiles*. Paris, 1875.
- *Mikroskopische Untersuchungen des Gespinnstfasern*. Zurich, 1873, 1882.
- Schmidt. *Schafzucht und Wollkunde*. 1852.

- Schneider and Kunzl. Spinnfasern und Färbungen im Ultramikroskop. Zeit. wiss. Mikrosk., Vol. 23, No. 4.
- Schubert. Die Zellulosefabrikation. Berlin, 1906.
- Schwalbe. Neuere Farbetheorien. Stuttgart, 1907.
- Der Abbau der Baumwoll-Cellulose. Berichte, 1910, p. 913.
- Die Chemie der Zellulose. Berlin, 1911.
- Schwarz. Mercerisation, in Muspratt's Handb. der Chem., Vol. 2, p. 915.
- Textilfasern. Muspratt's Handb. der Chem., Vol. 2, p. 849.
- Schwerdener. Ueber die Verschiebung der Bastfasern. Berichte.
- Schwick. On the Color of Nanking Cotton. London, 1873.
- On some Constituents of the Cotton Fiber. London, 1868.
- Botanisch. Gesellschaft, 1894.
- Scrive. Sur la rouissage et la culture du lin. Lille, 1867.
- Seabrook. Memoir on Origin, Cultivation and Uses of Cotton. Charleston, 1844.
- Serre. La fibre d'ananas de Java. Paris, 1907.
- Settegast. Bildliche Darstellung des Baues und der Eigenschaften der Merino-wolle. Berlin, 1869.
- Shepperson. Cotton Facts. New York.
- Sicard. Guide pratique de la culture due coton. Paris, 1866.
- Siegfried. Sur le coton de l'Algérie.
- Silberbach. Handbook of Vegetable and Mineral Products. Liverpool, 1887.
- Silk Culture in America. Manufacturers Rev., 1884, p. 301.
- Silvermann. Die Seide; 2 vols. Dresden, 1897.
- Fortschritte der chemischen Technologie der Gespinnstfasern, 1885-1900. Dresden, 1902.
- Singer. Apprêt et blanchiment du jute.
- Simmonds. Fibers and Cordage in British Manufacturing Industries, Vol. 9, p. 148.
- Sison. Leinbau und Flachsbereitung.
- Solaro. Studio microscopico e chimico delle Fibre. Milano, 1914.
- Spennrath. Das gefahrlose Karbonisieren der Wolle. Aachen, 1900.
- Materiallehre für die Textilindustrie, 1907.
- Squier. Tropical Fibers. New York, 1863.
- Stanwood. Flax, Hemp and Jute Products. U. S. Census Reports, Vol. 9, p. 235, 1900.
- Stellamonth. Katechismus des Seidenbaues. Leipzig, 1827.
- Stenckart. Die Baumwolle.
- Steven. Unterricht über den Seidenbau.
- Storck and Martin. L'industrie de la soie à travers des âges. Paris, 1890.
- Summers. Asbestos. London, 1919.

- Suvern. *Die künstliche Seide*. Berlin, 1912.
- Swab. *Fibrous Substances Indigenous and Exotic*. London, 1864.
- Swayne. *Silk Culture in England*. Technical Report, Vol. 7.
- Tariff Commission. *Flax, Hemp and Jute Industries*, 1905.
- Terwague. *Rouissage des plants textile*. Lille, 1853.
- *Du lin, du chanvre, etc.* Lille, 1852.
- Thomson. *The Sizing of Cotton Goods*. Manchester, 1875.
- Thorpe. *Dictionary of Applied Chemistry: Articles Relating to Textile Fibers*. New York, 1895.
- Tichonieroff. *L'embryologie du B. Mori*. Lyons, 1891.
- *Die Entwicklungsgeschichte der Seidenraupe*. Moscow, 1892.
- Tobler-Wolff. *Anbeitung zur mikroskopischen. Untersuchung von Pflanzenfasern*. Berlin, 1912.
- Todaro. *Relazioni sulla cultura dei cotonei in Italia*. Rome, 1878.
- Trotman and Thorpe. *The Principles of Bleaching and Finishing of Cotton*. London, 1911.
- U. S. Bureau of Standards. *Testing and Properties of Textile Materials; Circular 41*.
- U. S. Dept. of Agriculture. *Fiber Investigations*, 1892-98.
- *Yearbook*, 1903. *Silk Culture Bulletin*.
- U. S. Dept. of Commerce. *Linen, Jute and Hemp Industries in the United Kingdom*. Washington, 1913.
- U. S. Dept. of Agriculture. *The Cotton Plant*. Bulletin No. 33, 1898.
- Ure. *On the Cotton Manufacture of Great Britain*. London, 1861.
- *The Philosophy of Manufacture*. London, 1835.
- Valentin. *Untersuchung der Pflanzen- und Tiergewebe im polarisierten Licht*. 1861.
- Van der Ploeg. *Fibres de Bananiers*. Paris, 1903.
- Vautier. *L'art de la filature du coton*. Paris, 1821.
- Venerand. *Asbest*. Vienna, 1920.
- Veret. *Le lin et sa culture*. Paris, 1866.
- Vétillart. *Études sur les fibres végétales textiles*. Paris, 1876.
- Vignon. *La soie*. Paris, 1890.
- *Thermochemie due Seide*. Bull. Soc. Chem., Vol. 3, p. 405.
- Vinson. *Ueber die Seidenraupen Madagascars*. Comptes rend, Vol. 56.
- Wagner. *Chemical Technology: "Fibers," pp. 798-871*. Trans. Crookes. New York, 1897.
- *Handbuch der Physiologie: Artikel "Der Haut."*

- Wailley. *Wild Silks. Jour. Soc. Arts.*, 1883.
- Waldeyer. *Atlas der menschlichen und tierischen Haare.*
- Walmsley. *Cotton Spinning.* London, 1883.
- Walton. *The Story of Textiles.* Boston, 1912.
- Ward. *Flax: Its Cultivation and Preparation.* London, 1854.
- Warden. *The Linen Trade, Ancient and Modern.* London, 1864.
- Wardle. *An Examination into the Divisibility of the Silk Fiber.* Manchester, 1908.
- *Silk: Its Entomology, History and Manufacture.* London, 1887.
- *Handbook of Wild Silks of India.* London, 1881.
- *Descriptive Catalogue of Wild Silks.* London, 1886.
- *Chemistry of Tussah Silk. Text. Mfr.*, 1891.
- Watson (J. F.). *Fiber-Yielding Plants of India.* 1870.
- *Preparation and Use of Rhea Fiber.* London, 1875.
- (H. K.) *Textiles and Clothing.* Chicago, 1916.
- Watt. *Cotton.* London, 1877.
- *Economic Products of India,* 1889.
- Weddel. *Monographie des Urticées.* Paris, 1866.
- Wegscheider. *Mercerisation der Baumwolle.*
- Weiss. *Textiltechnik- und Handel.* 1907.
- Wiesner. *Beiträge zur Kenntniss der indischen Faserpflanzen.* 1870.
- *Die Rohstoffe des Pflanzenreiches; Vol. 2, "Fasern."* Leipzig, 1903.
- *Einleitung in die technische Mikroskopie.* 1867.
- *Mikroskopische Untersuchungen.* Stuttgart, 1872.
- Wiesner und Prasch. *Ueber die Sieden, in Mikroskop. Untersuchungen,* 1872, p. 45, und *Dingl. Polyt. Jour.*, 1868, p. 190.
- Wertheim. *Ueber den Bau des Haarbalges.* Vienna, 1864.
- Weyl. *Zur Kenntniss der Seide. Berichte,* Vol. 21, p. 1529.
- Wheeler. *A Handbook of Cotton Cultivation in Madras.* Madras, 1862.
- Willems. *La soie artificielle.* Paris.
- Winterbottom. *Marine Fiber. So. Australia Dept. Chem., Bull. No. 4.*
- Wissett. *A Treatise on Hemp.* London, 1808.
- Witt. *Chemische Technologie der Gespinnstfasern, Part I.* Brunswick, 1891. *Part II,* 1911; *Part III,* 1915.
- *Die Wilden Seiden. Moniteur Scient.,* 1887, p. 1366.
- Woldd. *Die Jute.* Berlin, 1913.
- Wolowski. *Sur l'introduction de l'industrie de la soie. Comptes rend.,* Vol. 34, p. 33.
- Worden. *Nitrocellulose Industry; 2 vols.* New York, 1911.
- Wranitzky. *Anleitung zur praktischen Seidenketten.* Frankfort, 1840.

- Zetzche. *Faserstoffe*. Leipzig, 1905.
 Zieten. *Anweisung zum Seidenbau*. Stuttgart, 1831.
 Zimmermann. *Ueber Pflanzenseiden*. *Der Pflanze*, Vol. 8, p. 177.
 Zinken. *Anweisung zum Seidenbau*. Braunschweig, 1829.
 Zipser. *Textile Raw Materials* (Trans. Salter). London, 1901.
 Zolla. *Les fibres textiles, d'origine animale*. Paris, 1910.

USEFUL BOOKS AND PERIODICALS

This is a limited list and has been selected as a good working beginning of a more extensive library for Textile Manufacturers and Mill Laboratories.

I.—TEXTILE FIBRES, MANUFACTURE, TESTS AND ANALYSES

- Advanced Textile Design—*Watson*
 Analysis of Woven Fabrics—*Barker and Midgley*
 Color in Woven Design—*Beaumont*
 Cost Accounting for Textile Mills—*Szepesi*
 Cotton Spinning—*Nasmith*
 Dress, Blouse and Costume Cloths—*Beaumont and Hill*
 Elementary Cotton Spinning, 2 vols.—*Thornley*
 Flat Machine Knitting and Fabrics—*Buck*
 Grammar of Textile Design—*Nisbet*
 Hosiery Manufacture—*Davis*
 Jacquard Mechanism—*Bradbury*
 Jute and Linen Weaving—*Woodhouse and Milne*
 Knitting Science—*Tompkins*
 Mechanism of Weaving—*Fox*
 Modern Flax, Hemp and Jute Spinning and Twisting—*Carter*
 Principles of Wool Combing—*Priestman*
 Principles of Woolen Spinning—*Priestman*
 Principles of Worsted Spinning—*Priestman*
 Raw Silk Properties, Classification and Throwing—*Seem*
 Report of Raw Silk Classification Committee—*The Silk Association of America*
 Sericulture—*Vieil*
 Silk Throwing and Waste Silk Spinning—*Rayner*
 Textiles—*Nystrom*
 Textile Calculations—*Whitwam*
 Textile Design and Color—*Watson*
 Textile Design, Pure and Applied—*Woodhouse and Milne*
 Theory of Silk Weaving—*Wolfensberger*

Union Textile Fabrication—*Beaumont*
 Wool—*Hart*
 Wool Substitutes—*Beaumont*
 Yarn Counts and Calculations—*Woodhouse*

II.—BLEACHING, DYEING, PRINTING AND FINISHING

Application of Coal Tar Dyestuffs—*Whittaker*
 Chemistry and Practice of Finishing, 2 vols.—*Bean and McCleary*
 Chemistry and Practice of Sizing—*Bean and Scarisbrick*
 Chemistry and Physics of Dyeing—*Dreaper*
 Dressing and Finishing of Textile Fabrics—*Polleyn*
 Dyes and Dyeing—*Pellew*
 Dyeing Silk, Mixed Silk Fabrics and Artificial Silk—*Grandswindt*
 Finishing of Jute and Linen Fabrics—*Woodhouse*
 Principles and Practice of Textile Printing—*Knecht and Frothergill*
 Textile Color Mixing—*Paterson*
 Water Softening and Treatment—*Booth*
 Waterproofing of Fabrics—*Mierzinske*
 Yarn and Warp Sizing—*Kretschman*

III.—CHEMISTRY AND BIOLOGY

Analytical Chemistry, 2 vols.—*Treadwell—Hall*
 Analysis of Dyestuffs—*Green*
 Analysis of Paint and Varnish Products—*Holley*
 Analysis of Minerals and Ores of Rarer Metals—*Schoeller*
 Applied Colloid Chemistry—*Bancroft*
 Bacteriology and Mycology of Foods—*Tanner*
 Bleaching—*Higgins*
 Catalysis in Theory and Practice—*Rideal and Taylor*
 Chemistry of Colloids—*Taylor*
 Chemistry of Dyestuffs—*Fort and Lloyd*
 Chemistry and Technology of Gelatine and Glue—*Bogue*
 Chemistry of Pulp and Paper Making—*Sutermeyer*
 Color in Relation to Chemical Constitution—*Watson*
 Determination of Radicles in Carbon Compounds—*Meyer—Tingle*
 Electro-Analysis—*Smith*
 Examination of Hydrocarbon Oils—*Mueller—Holde*
 Examination of Iron, Steel and Brass—*Hall and Williams*
 Food Inspection and Analysis—*Leach—Winton*
 Fresh Water Biology—*Ward and Whipple*
 Gas and Fuel Analysis—*White*
 Identification of Pure Organic Compounds, 4 vols.—*Mulliken*

Inks—*Mitchell*

Leather Industries Laboratory Book—*Proctor*

Methods in Metallurgical Analysis—*White*

Microorganisms and Fermentation—*Jørgensen*

Modern Inorganic Chemistry—*Mellor*

Modern Soaps, Candles and Glycerine—*Lamborn*

Organic Analysis—*Sherman*

Official Methods of Analysis—*Association of Official Agricultural Chemists*

Outline of Industrial Chemistry—*Thorpe*

Photo Chemistry—*Sheppard*

Physiological Chemistry—*Mathews*

Practical Physiological Chemistry—*Hawk*

Rubber, Resins, Paints and Varnishes—*Morrell and Waele*

Standard Methods of Chemical Analysis—*Scott*

Standards and Tests for Reagent Chemicals—*Murray*

Synthetic Coloring Matters—*Thorpe*

Synthetic Dyestuffs and Intermediate Products—*Cain and Thorpe*

System of Physical Chemistry, 3 vols.—*Lewis*

Technical Analysis of Brass and Non-Ferrous Alloys—*Price and Meade*

Technical Methods of Analysis—*Griffin*

Testing Dyestuffs in the Laboratory—*Whittaker*

Tests for Coal Tar Colors in Aniline Lakes—*Zerr and Mayer*

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 Thermodynamic and Free Energy of Chemical Substances—*Lewis and Randall*
 Ultra-violet Radiation—*Luckiesch*
 X-Ray and Crystal Structure—*Bragg*

V.—DICTIONARIES AND REFERENCE BOOKS

A. S. T. M. Standards—*American Society Testing Materials*
 Condensed Chemical Dictionary—*Chemical Catalogue Company*
 Dictionary Applied Chemistry, 5 vols.—*Thorpe*
 Dictionary Applied Physics, 5 vols.—*Glazebrook*
 Dictionary Chemistry, 4 vols.—*Watts*
 Dictionary Chemical Solubility—*Comey and Hahn*
 Dictionary Dyes, Mordants, etc.—*Rawson, Gardner and Laycock*
 Dictionary of Textiles—*Harmuth*
 Glossary Textile Terms—*Curtis*
 Mechanical Engineers' Handbook—*Marks*
 Physico-Chemical Tables, 2 vols.—*Castell and Evans*
 Smithsonian Physical Tables—*Fowles*
 Van Nostrand's Chemical Annual—*Olsen*

VI.—PERIODICALS

American Dyestuff Reporter—New York
 American Silk Journal—New York
 Analyst—London
 Chemical Abstracts—Am. Chem. Soc., Washington
 Chemical and Metallurgical Engineering—New York
 Color Trade Journal—New York
 India Rubber World—New York
 Industrial and Engineering Chemistry—Washington
 Journal American Chemical Society—Washington
 Journal of Biological Chemistry—New York
 Journal of Physical Chemistry—Ithaca, N. Y.
 Journal Society Chemical Industry—London
 Journal of Textile Institute—Manchester, England
 Paper Trade Journal—New York

Photographic Journal of America—Philadelphia
Physical Review—Corning, N. Y.
Silk—New York
Textile Colorist—New York
Textile World—Boston
Underwear and Hosiery Review—New York
Wool and Cotton Reporter, American—Boston

BIBLIOGRAPHY OF SOLVENT RECOVERY

- (1) Henri Barthelemy. "La Recuperation des Solvants Volatiles Employes dans l'Industrie des Matieres Plastiques." *Le Caoutchouc et la Gutta Percha*, 1914, pp. 8463 to 8473; 8515 to 8524; 8544 to 8548.
- (2) Maurice Deschiens. "Procedes Industriels de Recuperation des Dissolvants Volatiles et Comparaison de ces Procedes." *Revue des Products Chimiques*, Mai 15, 1920.
- (3) Charles Mariller. "La Recuperation des Liquides Volatiles dans l'Industrie." *La Technique Moderne*, September, 1920, pp. 361 to 373.
- (4) Dr. G. Weissenberger. *Kunststoffe*, Nos. 15 and 16, August, 1921.
- (5) Dr. G. Weissenberger. "Ueber die Chemischen Grundlagen des Kresols Verfahrens." *Kunststoffe*, 1924, No. 3.
- (6) Dr. G. Weissenberger. "Mitteilungen des Niederrheinischen Bezirksvereins des Vereins Deutscher Ingenieure," 1927, No. 4.
- (7) Irvine Masson and T. Lawson McEwan. "The Recovery of Solvent Vapours from Air—The Use of Cresol and of Sulphuric Acid for Ether and Alcohol." *Journal of the Society of Chemical Industry*, February 28, 1921, pp. 32T to 38T.
- (8) Ministry of Munitions and Department of Scientific and Industrial Research. Technical Records of Explosive Supply, 1915-1918. Pamphlet No. 8, "Solvent Recovery." 1921. H. M. Stationery Office, Imperial House, Kingsway, London, W.C.2.
- (9) J. H. Bregeat. "Recuperation-Extraction des Produits Volatils." *Science et Industrie*, No. 163, 1927, pp. 71 to 83.
- (10) M. Roulleux and Robert G. Dort. "Recovery of Volatile Solvents by the Bregeat Process." *Chem. and Met.*, Vol. 24, No. 21, May 25, 1921.
- (11) Clark S. Robinson. "The Recovery of Volatile Solvents." 1922, Ed. Chemical Catalog Co., 188 pages.
- (12) Dr. A. Schrimpf. "Die Explosion in der Pulverfabrik Hasloch am 20 Mai 1926." *Zeitschrift fur das Gesamte Schiess- und Sprengstoffwesen*, No. 3, March, 1927, pp. 45 to 48, edited 14 Ludwigstrasse, Munich, Germany.

INDEX

- Absorbents, solid, 603
- Absorption process, sulphuric acid, 591
 - in cresol, 593
 - in water, 592
- Acetate Rayon, American pioneers in, 559
 - chemistry of, 564
 - dyeing of, 708
 - first plant to produce, 559
- Acetate plant, design of, 578
 - equipment of, 579
- Acetate process, economies of, 577
 - history of, 559
 - recovery in, 588
 - requirements of, 570
 - solvents in, 581
- Acetate silk companies, organization of, 11
- Acetate yarn, chemical treatment of, 575
 - development of, 563
- Acetation of cellulose, 567
- Acetone soluble cellulose acetate, 11
- Acetyliizer mixer, 570
- Acid elimination, 501
 - recovery, 557
 - tanks, 620
- Acme Rayon Corporation, particulars regarding, 57
- Activated carbon, use of, 604
- Advertisements, specimens of, 287-290
- Advertising, 284
- Air bubble removal, 326
- Air conditioning considerations, 394
 - equipment, 395
 - unit, 398
- Air purification, 481
- Alkali cellulose, patents on purifying, 773
- Alkali cellulose, process, Ivrea, 621
- Alpha pulp, Rayon, 428
- American Bemberg Corporation, 58
- American Chatillon Corporation plant, 12
- American Enka Corporation, 60
- American Glanzstoff Corporation, 59
- American-made Rayon *vs.* European, 291
- American pioneers in cellulose acetate, 559
- American silk yarns, 850
- American Viscose Rayon plant, 12
- Analysis of pulp, 428
- Apparatus, specially designed, 331
 - of general application, 330
- Arnheim plant, 663
- Artificial horsehair, 130
 - duty on, 315
- Artificial ribbon, 131
- Artificial silk, early production of, 2
 - producers of, 879
 - industry, patents on, 803
 - yarns, count of, 849
- Artificial straw, 131
- Artificial wool, 130
- Asia, Rayon production and plants, 114
- Austrian Rayon plants and production, 104
- Avoirdupois and metric weights, 811
- Basic colors, dyeing with, 700
- Beeswax as coating, 652
- Belamose Corporation, particulars regarding, 57
- Belgian Rayon plants and production, 99
- Belgium, producers in, 879
- Bemberg plant, 636
- Better Business Bureau Bulletin, 227

- Bicarbonate, 363
- Biology, literature on, 876
- Bleaching, object of, 422
- Bleaching agent, literature on, 604
- Bleaching and dyeing, Ivrea, 624
- Blending, 453
- Bobbin dryer, 486
 - drying, 628
 - method, 462-482
 - spinning method, 483
- Bobbins, 642
 - operation of, 473
 - washing of, 484
- Books and periodicals, 875
- Boiling kier, 528
- Bradford Durfee Textile School in-
 - vestigations, 36
- Brazil, producers in, 880
- Brazilian production, 62
- Bregeat process, 593
- Breakages, eliminating, 656
- Buildings, types and design, 356, 635
- Burlington, No. Car., Rayon plant at,
 - 61
- Calcium and magnesium, 362
- Calcium bisulphite solution, 422
- Canada, producers in, 881
- Canadian production, 61
 - Rayon plants, 61
- Candle filters, 468
- Capital requirements, 515
- Capitalization, 137
- Carbon, activated, 604
 - disulphide, 441
 - reaction of, 450
- Cataldi-Pomilio process, 585
- Caustic soda in Rayon plant, 441
 - recovery, 584
- Celanese, 10
 - American production of, 561
 - corporation, alliances of, 15
 - particulars regarding, 56
- Celaphane, production of, 121
- Cellulose, acetation of, 467
 - baling wood, 427
 - chemical formula for, 566
 - determining alpha, beta and gamma, 736
- Cellulose, mixing, 447, 450
 - nitration of, 547
 - patents on, 750, 762
 - physical properties of, 414
 - wood, 415
- Cellulose acetate, acetic acid recov-
 - ery, 603
 - acetone soluble, 11
 - American pioneers in, 559
 - developments in, 560
 - precipitation of, 573
- Cellulose acetate process, 10
 - flow sheet of, 14
 - tests for, 746
- Cellulose crumbs, maturing, 448
 - diacetates, 567
 - esters, patents, 803
 - filaments, patents treating, 770-780
 - formate silk, patent, 803
 - from cornstalks, flax and straw, 433
 - by chlorine gas process, 585
 - monacetates, 567
- Cellulose nitrate, preparation of, 548
 - transforming purified cotton into, 547
- Cellulose Rayon, dyeing of, 704
- Cellulose sheets, soaking, 445
- Cellulose silk, patents on, 802
- Cellulose solutions, products obtained
 - from, 120
- Cellulose triacetate, obtaining of, 568
- Centrifugal spinning pot, 475
- Chardonnet process, history of, 544
 - modification of and steps in, 7
 - Rayon, materials in, 545
- Chatillon Company, history, 612
 - mills, 615
- Chemical composition, 805
 - purpose and structure of, 797
- Chemical Foundation, patents con-
 - trolled by, 801
- Chemical formula for cellulose, 566
- Chemical processes, control of, 395
- Chemicals, recovery of, 543
- Chemicals in processes, 581
 - used in making Rayon, 433.
- Chemistry, books on, 876
- Chemistry of acetate Rayon, 564
- China, producers in, 881

- China grass fiber, 210
- Chinese weights and measures, 817
- Chloride, 364
- Chlorine gas process, cellulose by, 585
- Chronological table of principal events, 38
- Cleansing agents, patents on, 804
- Clemson College course, 36
- Coagulability, 232
- Coagulating, 457
 - bath, effect of, 329
- Coagulation, chemical control of, 370
- Cocoons, silkworm, 217
- Colloidal solutions, 195
- Colors, dyeing with direct, 701
 - Anthrene, 703
- Common textile fibers, 181
- Companies, expansion of, 177
 - factories and, in operation, 46
 - financial reports of operating, 139
 - producing Rayon in Great Britain, 69
- Compounds, preparation of, 647
- Cones and spools, 280
- Consolidation tendencies, 307
- Consolidations of Rayon companies, 307, 310
- Constituents, ratio between various, 417
- Consumer's advertisements, 287-290
- Consumption, production and imports by United States, 51
- Consumption of Rayon, 255, 258
- Containers, treatment of paper, 122
- Contamination, sources of, 391
- Control, Rayon companies group, 310
- Control laboratories, Chatillon, 617
- Control tests, Viscose process, 732
- Conversion factors, 818, 822
- Copper number, determining, 733
- Copper solutions, patents on, 762, 763, 767
- Cornstalks, cellulose from, 433
- Cost of steam power, 403
- Cotton, 196
 - cellulose from, 432
 - nitration of, 546
 - transforming purified, 547
- Cotton and artificial silk, numbering of, 821
 - regain, 824
 - yarn by weight, numbering, 833
- Cotton and Rayon, 681
- Cotton fibres, 202
 - filled goods, 688
 - linters, 432
 - mills consumption of Rayon, 261
 - solution mixer, 532
 - warp, 684
- Courses by Clemson College, 36
 - in New York University, 37
- Courtaulds, Ltd., production by, 62
- Cresol system, costs and earning power of, 601
- Crinol, 130
- Cross and Bevan, study of processes by, 8
- Cupra-ammonium process, by Pauly, 8
 - chemical characteristics in, 526
 - Despeisses, 7
 - flow sheet of, 13
 - history of, 523
 - patents covering, 759
 - raw materials in, 523
 - recovery in, 587
 - solvents in, 581
 - steps in, 524
 - tests for, 744
- Cupra-ammonium Rayon, chemicals used in, 971
 - silk, patents on, 801
 - solution, control test of, 532
 - filtration of, 533
 - patents on, 759
 - preparation of, 529
- Czecho-Slovak Rayon plants and production, 105
- De-aeration, 456
- de Chardonnet, Count Hilaire, 4
- Decomposing poisonous gases, 481
- Decorating a woven design, 681
- Definitions, 724
- Delaware Rayon Corporation, particulars regarding, 57
- Delustering, 714

- Denier Table, 856
- Denitrating, patents covering, 754
- Denitration, 555
- Department of Commerce data, 276
- Despeisses, cupra-ammonium process of, 7
- Design and construction of plants, 354
- Development considerations, 405
- Development and growth table, 38
- Dictionaries, 878
- Digesters, 422
- Disposition of worn-out Rayon garments, 34
- Dreyfuss cellulose acetate, 11
- Drying and humidifying, 492
 - washing, patents on, 786
- Drying bobbins, 628
- Drying of Rayon, 346
 - under tension, 502
- Du Pont plant, 609
- Du Pont Rayon Company, 11, 55
- Dutch Enka plants, 633-634
- Duty on Rayon, 311
- Dyeing, books and periodicals on, 876
 - uniformity of, 736
- Dyeing and bleaching, Ivrea, 624
- Dyeing machines for Rayon yarn, 698
 - with basic colors, 703
- Dyeing Rayon yarn, 281
- Dyeing with anthrene colors, 703
 - with direct colors, 701
 - of Rayon yarns, 703
- Dyestuffs, classification of Viscose, 705
 - classified vat, 707
- Earnings *vs.* production, 136
- Economic production, 507
- Economics, trade, 225
- Ede plant, 634
- Elasticity, 721
 - of Rayon, 655
- Elongation, 721
- Engineering of process details, 411
- Engineering problems, 353
- England, producers in, 802
- Equipment, air conditioning, 395
 - choice of, 388
- Equipment, for making Rayon, 330
 - modified textile, 350
 - of acetate plant, 579
 - plant, 512
- Equivalents, fundamental, 809
 - metric, 810
- Estimates of Fairchild Analytical Bureau, 118
- European prices, 293
 - production, 63
 - Rayon *vs.* American, 291
- Europeans, vision of, 176
- Expansion of companies, 177
- Experiments and research work, 35
- Exports and imports, 294
- Fabrics, finishing, 710
 - Rayon and silk, 675
 - sizing for, 123
 - of Rayon, 667
- Factories in operation and under construction, 46
- Federal Trade Commission resolution, 226
- Fibre, coating the, 649
- Fibres, cotton, 202
 - flax, 208
 - spinning, 128
 - staple, 127
 - wool, 207
- Fibres and yarns, analysis of, 846
- Filament, handling and processing of, 329
 - material, strength of, 323
 - twisting and spooling, 486
- Films from cellulose acetate, 120
- Filter presses, 535
- Filtering devices, patents on, 781
- Filters, 379
 - candle, 468
- Filtration, 455, 533
 - and softening plant, modern, 390
 - patents on, 751
- Financial aspects, 133
 - reports of operating companies, 139, 170
 - structure of Rayon producers, 139
 - struggles, review of early, 292
- Finished goods, classification of, 292

- Finishing, 556
 - fabrics, 710
 - patents on, 787
- Flax, cellulose from, 433
 - fibre, 208
- Floor space required to produce Rayon, 479
- Flow sheet, cupra-ammonium process, 13
 - cellulose acetate process, 14
- France, producers in, 807
- French Rayon plants and production, 86
- Fuel considerations, 402
- Furness Corporation, 61
- Future of Rayon, 20
- Garnetted waste, 127
- Gases, decomposing poisonous, 481
- German Rayon plants and production, 77
- Germany, producers in, 811
- Gingham Rayon decorated, 685
- Glass, unshatterable, production of, 121
- Glossary of Rayon fabrics, 664
- Godet roller, 474
- Goose-neck, glass, 470
- Grading and sorting, 493
- Grading, sorting and packing, 625
- Great Britain, Rayon plants in, 70
 - Rayon production in, 68
- Greece, producers in, 814
- Greek Rayon plants and production, 111
- Gummy matter, determining, 735
- Hardness in water, 365
- Heat, tables on, 845
- History of Rayon, 1
 - Holland, producers in, 814
 - Rayon plants and production in, 98
- Hollow filament yarn, 124
- Hooke, views of Dr. Robert, 2
- Horsehair, artificial, 130
- Hosiery industry, 272
- Humidifying and drying, 492
- Humidity regulation, 394
- Hungarian Rayon plant and production, 111
- Hungary, producers in, 815
- Importance to American market of Rayon, 33
- Imports by United States, 51
- Imports and exports, 294
- Improvement tendencies, 520
- India, producers in, 815
- Industrial Rayon Corporation, particulars regarding, 56
- Insulation plates, 123
- Interior decorating with Rayon, 688
- International trade economics, 291
- Investigations of Bradford Durfee Textile School, 36
 - of Philadelphia Textile School, 37
- Investors, foreign, 176
- Ireland, producers in, 815
 - Rayon plants and production in, 113
- Iron, 362
- Italian production, 63
- Italy, producers in, 816
- Ivrea mills, 619
- Jamaica, producers in, 818
- Japan, producers in, 818
 - raw silk regain in, 840
- Japanese Rayon plants and production, 114
 - weights and measures, 816
- Jute and heavy flaxes and hemp, numbering of, 822
- Judging Rayon fabrics, 282
- Keller, F. G., invention of, 2
- Knitted goods, 657
- Knitting, 659
 - industry, Rayon hold on, 239
- Labor conditions. 407
 - hours, 409.
- Laboratory work and lectures at Lowell Textile School, 35
- Lacquers and paints, cellulose solution used in, 122
- Layout and design of plant, 511

- Leather, Viscose, 123
 Life of Rayon industry, continuity of, 34
 Linen, 208
 and hemp, numbering of, 832
 Lining men's clothing, 249
 Linters, cotton, 432
 purification process of, 566
 Linters pulp, production of, 432
 Living conditions, 407
 Location considerations, 412
 of plants, 355
 "Lolustra" yarn, 132
 Lowell Textile School lectures and laboratory work, 35
 Lubricating Rayon yarn, 658
 Lustre removal, patents on, 787
 Lustron Company, history of, 560

Machines, patents on spinning, 783
 Massachusetts Institute of Technology test, 36
 Materials, principal, 414
 Maturing cellulose, 448
 Mechanical processes of nitration, 549
 Mercerizing process, 445
 Merchandizing, 278
 Metallic gauze, covering for, 123
 Methods of producing, patents on, 750
 Metric and avoirdupois weights, comparison of, 811
 Mills, modern Rayon, 607, 635
 Mixtures, Rayon and wool, 676
 Moirés, making, 675
 Mordant, use of, 701

Nails, 127
 Needle knitter, 661
 Neutrasol, 648
 New Bedford Textile School, experiments and research work, 35
 New York University classes, 37
 Nitrate, 364
 Nitration, mechanical processes of, 549
 of cotton, 546
 Nitration conditions, 549
 process, 548

 Nitro process, history of, 544
 steps in, 546
 Nitro-Rayon, patents on fireproofing, 755
 raw, materials in, 545
 Nitrocellulose, discovery of, 3
 process, 7
 recovery in, 588
 solvents in, 581
 Nitrocellulose process, patents on, 747, 750, 751, 752, 801
 tests for, 738
 Non-regenerative process, 12
 Norway, Rayon production and plants in, 114

Oiling Rayon yarn, 657
 Old hickory, 608
 Opaquing, patents on, 787
 Operating companies, financial reports of, 139
 Operating plants, problems in establishing, 354
 location of, 355
 Operators, skilled, 642
 Opinions, business leaders', 246
 Rayon authorities, 18
 Rayon producers, 30
 Organization of acetate silk companies, 11
 Oriental production of Rayon, 34
 Orifice feed, manually controlled, 373
 Original process of nitration, 549
 Oxygen in cellulose, 450

Packing, sorting and grading, 625
 Paints and lacquers, cellulose solution used in, 122
 Paper and metallic gauze, covering for, 123
 Paper containers, treatment of, 122
 Patent, first English, 544
 Patents, 747
 controlled by Chemical Foundation, 801
 of interest, 750
 Pauly process, 8
 Percentages of Rayon produced under different processes, 12

- Periodicals and books, 875, 878
- Philadelphia Textile School, investigations and tests of, 37
- Photography, books on, 873
- Physics, books on, 873
- Plant, equipment of, 512
 - layout and design of, 505, 511
 - skilled technicians in, 520
- Plant capitalization, 137
- Plant organization, 137
- Poland, Rayon plants and production in, 108
- Pot spinning, 463
- Power and Transformer House, 631-632
- Power considerations, 402
- Preparation of spinning bath, 457
 - solutions, 325, 552
- Preparing yarn, 482
- Price comparison, Rayon and silk, 243
 - fluctuation, 250
 - trends, 240
- Prices, European, 293
- Principles, fundamental, in Rayon production, 319
- Process, acetate, history of, 559
 - alkali-cellulose, 621
 - Bregeat, 593
 - Cataldi-Pomilio, 585
 - control of steps in, 424
 - cupra-ammonium, 523
 - history of Viscose, 436
 - pot, 549
 - solvent recovery, 603
 - spinning, 327
 - steeping or mercerizing, 444
 - sulphuric acid absorption, 591
- Process details, engineering of, 411
- Processes, abbreviated, 350
 - classification of, 7
 - control of chemical, 395
 - degenerative influence of, 13
 - four Rayon, 351
 - non-regenerative and regenerative, 12
 - review of various, 590
 - patents on spinning, 783
- Processes of nitration, mechanical, 549
- Processing, 638
- Producers, financial structure of, 139
- Producing companies, organizing Rayon, 431
- Production, Rayon, 45
 - reducing cost of, 581
 - requisites for proper, 319
 - volume of, 34
- Production by countries, 50
 - in Europe, 63
 - in United States, 33
 - possibilities, 118
 - vs.* earnings, 136
- Production of fancy weaves, 666
- Proportionating feed, 376
- Public interest, 230
- Pulp, analysis of, 428
 - barking plant, 420
 - bleaching, 424
 - examination of, 428
 - preparation of, 419
- Pulp sheets, conversion into, 424
 - cutting, 426
- Pulp suspension, conversion of, 424
- Pumps, pressure, 332
 - Rayon spinning, 333, 465
- Purification of raw material, 546
- Quality, comparative, 119
- Ramie, 210
 - numbering of, 822
- Raw materials, 545
 - basic and principal, 414
 - concentration of, 431
 - cupra-ammonium, 523
 - essential characteristics of, 437
 - purification of, 525, 546
 - water as, 434
- Raw silk and Rayon, relative world production of, 47
- Rayon, acetate, first plant producing, 559
 - adopting name, 16
 - American made *vs.* European, 291
 - approval of name, 226
 - channels opened by use of, 132
 - characteristics of, 181, 193
 - Chardonnet, 190

- Rayon, chemicals used in making, 433
 chemical equipment for making, 330
 commercially successful processes for making, 414
 composition of, 647
 consumption by industries of, 240
 255, 258, 261, 264
 cooling, 485
 cupra-ammonium, 191
 definition of, 228
 delustered, 131
 determining titer of, 718
 development of, 17
 duties on, 312
 drying and storing, 346, 485
 dyeing of, 281, 704
 elasticity of, 655
 facts about, 227
 floor space for plant producing, 479
 future of, 20
 Glanzstoff, 191
 history of, 1
 importance to American market of, 33
 interior decorating with, 688
 major outlets of, 257
 market for, 33
 meaning of word, 16
 mechanical properties of, 186
 merchandizing, 278
 nitro, 190
 Oriental production of, 34
 patents treating on, 778
 physical properties of, 182
 process of producing, 319
 process production, percentages of, 12
 production of, 45
 production possibilities of, 118
 progress here and abroad of, 18-33
 proper production of, 319
 reducing production cost of, 581
 reeling and lacing, 487
 reeling of, 352
 relative world production of raw silk and, 47
 sales of, 234
 size for, 647
- Rayon, sorting, 542
 spinning, 536
 spun, 127
 stretching, 485
 superiority of American made, 291
 total production in United States of, 33
 twisting of, 350
 uniformity of, 722
 use of term, 231
 varieties of, 228
 Viscose, 189
 washing of, 346
 weaving of, 653
 world production of, 33
- Rayon alpha pulp, 428
 Rayon and silk, price comparison, 243
 Rayon authorities, opinions of, 18
 Rayon bobbins, washing, 484
 Rayon companies group, control, 310
 consolidations, 307, 310
 Rayon decorated gingham, 685
 Rayon equipment, European, 515
 Rayon exportation from Italy, 63
 Rayon fabrics, 667
 glossary of, 664
 judging, 282
 Rayon fibres, patents on making, 778
 Rayon filament, making of, 44
 preparation of, 774
 Rayon-filled fabrics, 684
 Rayon from aspen poplar, 416
 paper birch, 416
 spruce, 416
 Rayon garments, disposition of worn-out, 34
 Rayon hold on knitting industry, 239
 Rayon industry, birth of, 6
 consolidation tendencies in, 307
 continuity of life of, 34
 events, table of, 38
 importance and growth of, 16, 38
 necessity for water in, 393
 Rayon Institute, purposes of, 36
 efforts, 230
 Rayon making, problems of, 136
 Rayon manufacture, first English patent in, 544
 patents on processes of, 780

- Rayon manufacturers, Italian, 64
- Rayon mills, modern, 607-635
- Rayon on bobbin, guiding, 472
- Rayon patents treating Viscose, 778
- Rayon plant, caustic soda in, 441
 - examples of an operating, 413
 - proper size, 510
- Rayon plants, design and construction of, 354
 - location of, 407
 - summary, 60
 - in Asia, 114
 - Austria, 104
 - Belgium, 99
 - Brazil, 62
 - Canada, 61
 - Czecho-Slovakia, 105
 - France, 86
 - Germany, 77
 - Great Britain, 70
 - Greece, 111
 - Holland, 98
 - Hungary, 111
 - Ireland, 113
 - Italy, 63, 68
 - Japan, 114
 - Norway, 114
 - Poland, 108
 - Russia, 109
 - Spain, 109
 - Switzerland, 102
- Rayon processes, four, 351
 - patent literature on, 747
- Rayon producers, 879
 - financial structure of, 139
- Rayon producing companies, organizing, 431
- Rayon producing companies in United States, 54
- Rayon production, acetic acid recovery, 603
 - floor space for, 509
 - fundamental principles in, 319
 - growth by years and countries of, 45
 - in Great Britain, 68
 - raw materials for, 415
 - vs.* sericulture, 24
 - wood pulp for, 428
- Rayon products, 685
- Rayon pulp, high quality, 419
- Rayon securities, appreciation of, 176
 - future of, 179
- Rayon shares, marketing, 180
- Rayon silk, patents on, 802
- Rayon skein, bundling and packing, 495
- Rayon solution, patents on preparation of, 772
- Rayon spinning machine, vanguard of, 3
- Rayon spinning pump, 333
- Rayon standards, 724
- Rayon supply and demand, 239
- Rayon underwear, 268
- Rayon warp, 688
 - preparing, 654
- Rayon waste, 124
- Rayon wood-pulp specifications, 430
- Rayon yarn, bleaching tests for, 196
 - consumption of, 253
 - dyeing of, 703
 - machines for, 698
 - fortifying, 652
 - luster of, 184
 - measuring and testing, 716
 - numbering, 718
 - oiling, 657
 - prices of, 247
 - purchase of, 638
 - rates of duty on, 315
 - soaping and sizing, 195
 - softening and lubricating, 658
 - tenacity and elasticity of, 187
 - various types of, 253
- Rayon and cotton, 681
- Rayon and silk fabrics, 675
- Rayon and wool combination, 686
 - mixtures, 676
- Reaction of cellulose, 567
- Réaumur, Rene A. F., 2
- Recovery of solvent and acid, 557
- Recovery process, solvent, 603
- Recovery towers, solvent, 596
- Reel stretch spinning, 452
- Reeled skeins, final treatment of, 489
- Reeling, 630
- Reeling and lacing, 487

- Reeling machines, 498
- Reeling of Rayon, 352
- Regenerated cellulose Rayon, dyeing of, 704
- Regenerative processes, 12
- Relative humidity, 842
- Removability, 659
- Reports, financial, of operating companies, 139
- Research laboratories considerations, 405
- Research work, 439
- Ribbon, artificial, 131
- Ripening, 454
- Ripening of solution, 326
- Ripening Tanks, Viscose, 627
- Roller, Godet, 474
- Rosland Corporation, 59
- Rubber, Viscose, 123
- Russian Rayon production and plants, 113
- Sales of Rayon, 234
- Satins and twills, 674
- Sausage casings, production of, 121
- Securities, future of Rayon, 179
- Sericulture *vs.* Rayon production, 24
- Settling tank, 377
- Shredding, 447
- Silica, 361
- Silica gel, absorption in, 605
- Silk, definition of, 220, 229
 - names denoting, 229
 - numbering of, 820
 - raw, 224
 - spinning from floor, 223
 - value proportions for thrown, 851
- Silk industry consumption of Rayon, 258
- Silk table, 855
- Silk to pound, yards of, 834
- Silkworms, feeding the, 217
 - study of, 4
- Silk yarns, numbering, 717
- Site, selection of, 355
- Sizing, 645
 - application of, 651
- Sizing for fabrics and threads, 123
- Sizing Rayon yarn, 195
- Skein dryer, 504
- Skeins, 280
 - bundling and packing, 495
 - treatment of reeled, 489
- Skenandoa Rayon Corporation, 58
- Slivers, 126
- Soaping Rayon yarn, 195
- Sodium and potassium, 363
- Softeners, water, 382
- Softening plant, modern filtration and, 390
- Softening Rayon yarn, 658
- Solution, calcium bisulphite, 422
 - coagulability of, 323
 - colloidal, 195
 - cupra-ammonium, 529
 - preparation of spinning, 325
 - preparing spinning, 552
 - products from cellulose, 120
 - shredding the, 447
 - spinning, 320
 - viscosity of, 320
- Solutions, preparation patents on cupra-ammonium, 753
- Solvent recovery, 557
- Solvent recovery towers, 596
- Solvents, principal chemicals and volatile, 581
- Sorting, grading packing, 625
- Sorting and grading, 493
- Spanish Rayon plants and production, 109
- Specific solvents, patents on, 751
- Spinnerets, 335
 - accuracy specifications for, 337
 - arrangement of, 339
 - Brausen, 337
 - evolution of, 342
 - function of, 335-470
 - glass, 336
 - metal, 336
 - operation of, 470
 - patents on, 782
- Spinning, definition of, 44
 - Ivrea, 623
 - pot method of, 473
- Spinning bath, development of, 458
 - preparation of, 457
- Spinning fibres, 128

- Spinning machine, vanguard of Rayon, 3
- Spinning machines, 462
- Spinning of solutions, patents on, 752
- Spinning pot, centrifugal, 475
- Spinning process, development of
 - first, 327, 436
 - theory of, 328
- Spinning processes and machines,
 - patents on, 783
- Spinning pump, 333
- Spinning pumps, 465
- Spinning solution, coagulability of,
 - 323
 - preparation of, 325, 552, 574
 - ripening of, 326, 454
 - Viscose, 452-460
 - viscosity of, 320
- Spinning solutions, 320
- Spinning Rayon, 536
- Spinning Viscose solution, 460
- Spooling, patents on, 751, 785
- Spooling and twisting filaments, 486
- Spools, 280
- Spruces for production of Rayon, 416
- Spun thread, finishing, 540
 - gathering, 345
- Standard machines regain, 838
- Steam considerations, 402
- Steam power, costs of, 403
- Steam requirements, 404
- Steeping press, 446
- Steeping process, 444
- Straw, artificial, 131
 - cellulose from, 433
- Strength, 726
- Stretch spinning, 538
- Stretch spinning process, 327
- Stretching, 639
- Sulphate, 364
- Sulphidizing, Ivrea, 622
- Sulphite wood pulp, production of,
 - 61
- Sulphuric acid, 442
- Sulphuric acid absorption process,
 - 591
- Supply and demand, 239
- Swiss Rayon plants and production,
 - 102
- Table of events, growth and development, 38
- Table of hardness, conversion, 805
- Tables, 806, 856
- Tank, settling, 377
- Tanks, Chatillon Mills, 618
 - Viscose ripening, 627
- Tariffs, 311
- Technicians in plants, 520
- Temperature and humidity, 660
- Temperature regulation, 394
- Tensile strength, 721
- Testing, 721
- Tests of Massachusetts Institute of Technology, 36
- Tests and test methods, 725
- Textile equipment, modified, 350
- Textile fibres, books on, 875
 - characteristics of common, 181
- Textiles, relative prices of, 246
- Thermostats, function of, 401
- Thread, finishing of spun, 540
 - gathering spun, 345
 - production of the, 565
 - sizing for, 123
- Thread bunching, 640
 - formation, patents on, 752
- Thread produced by Audemars, 545
- Threads, diameters of, 835
- Thrown silk, value proportions for,
 - 851
- Tipping-meter feed, 375
- "Topham" box, 9
- Tops, 126
- Trade economics, 225
 - international, 291
- Trade marks, 229
- Transportation considerations, 406
- Tricollette, 663
- Tubes, 280
- Tubize Artificial Silk Company of
 - America, 56
- Twills and Rayons, 674
- Twist of Rayon, 722
- Twisting, 629
 - patents covering, 752-785
- Twisting filaments, 487
- Twisting of Rayon, 350
- Types and design of buildings, 356

- Underwear, Rayon, 268
 Underwear industry, consumption of
 Rayon by, 264
 United States Consumption, Pro-
 duction and Imports, 51
 United States patents, 788-795
 Useful tables, 856
- Varieties of Rayon, 229
 Vat dyestuffs, classified, 707
 Vercelli mills, 626
 Viscose, patents on preparation of
 Rayon filaments from, 774
 Viscose cellulose solutions, products
 from, 120
 Viscose Company, particulars regard-
 ing, 54
 Viscose dyestuffs, classification of,
 705
 Viscose filament, character of, 459
 Viscose industries, development of, 10
 Viscose leather, 123
 Viscose plants, 610-611
 Viscose process, capital requirements,
 515
 control tests for, 732
 development and operation of,
 8, 9
 history of, 436
 natural advantages of, 15
 patents on the, 772, 776
 plant design for, 505
 raw materials in, 437
 recovery in, 582
 solvents in, 581
 Viscose Rayon, 189
 chemicals in, 442
 Viscose ripening tanks, 627
 Viscose rubber, 123
 Viscose solution, chemical plant, 443
 preparation of, 443
 spinning of, 460
 Viscose spinning solution, 452
 blending, 453
 ripening, 454
 Viscosity, measurement of, 322
- Wages, 408
 Wallpaper surfacing, 122
- Warp, preparing Rayon, 654
 Warping and beaming, 655
 Washing machines, 501
 Washing of Rayon, 346
 Waste, bobbin or winding, 125
 definition of various classes, 125
 garnetted, 127
 mill, reeling, soiled, spinning, 125
 Rayon, 124
 Waste Opener, "Garnett," 128
 Water, analysis of, 389
 comparative costs of, 389
 filtration of, 367
 hardness in, 365
 industrial uses of, 361
 Water as a raw material, 434
 Water considerations, 361
 requirements, 358
 softness, 382
 Water to process, relation of, 392
 Waterproofing production, 122
 Weaving, 653
 looms for, 655
 Weaving looms, 656
 Weighing, patents on, 787
 Winding operation machines, 642,
 643
 Winding Rayon yarn, 657, 663
 Wood, chemical composition of, 415
 common kinds of, 416
 Wood cellulose, 415
 baling, 427
 Wood giving best results, 417
 Wood pulp, 415
 cellulose in, 415
 chemical properties of, 417
 chemical content of, 428
 importation of, 438
 suitability of, for Rayon produc-
 tion, 428
 Wood pulp as basic material, 438
 Wood-pulp specifications, 430
 Wood storage, 421
 Wool, artificial, 130
 Wool fibres, 207
 Wool and Rayon combination, 686
 mixtures, 676
 Woolen fibres, numbering of, 821
 soap curds on, 392

- Woolen yarns, 836
 - size of, 717
- Working hours, 409
- World production of raw silk and Rayon, 47
- World production of Rayon, 33
- Worsted regain, 839
- Worsted yarns, 835
 - sizes of, 717
- Woven goods, 639
- Woven design, decorating a, 681
- Xanthate to Viscose mixing, 452
- Xanthating, 450
- Yard traffic regulations, 406
- Yarn, finishing of, 482, 496
 - hollow filament, 124
 - "Lolustra," 132
 - purchase of, 638
 - winding, 640
 - worsted, 835
- Yarn count conversion factors, 822
 - numbering, 835
- Yarns, comparative table, 832
 - dyeing various Rayon, 698
 - in fabrics and fibres, analysis of, 846
 - measuring and testing Rayon, 716

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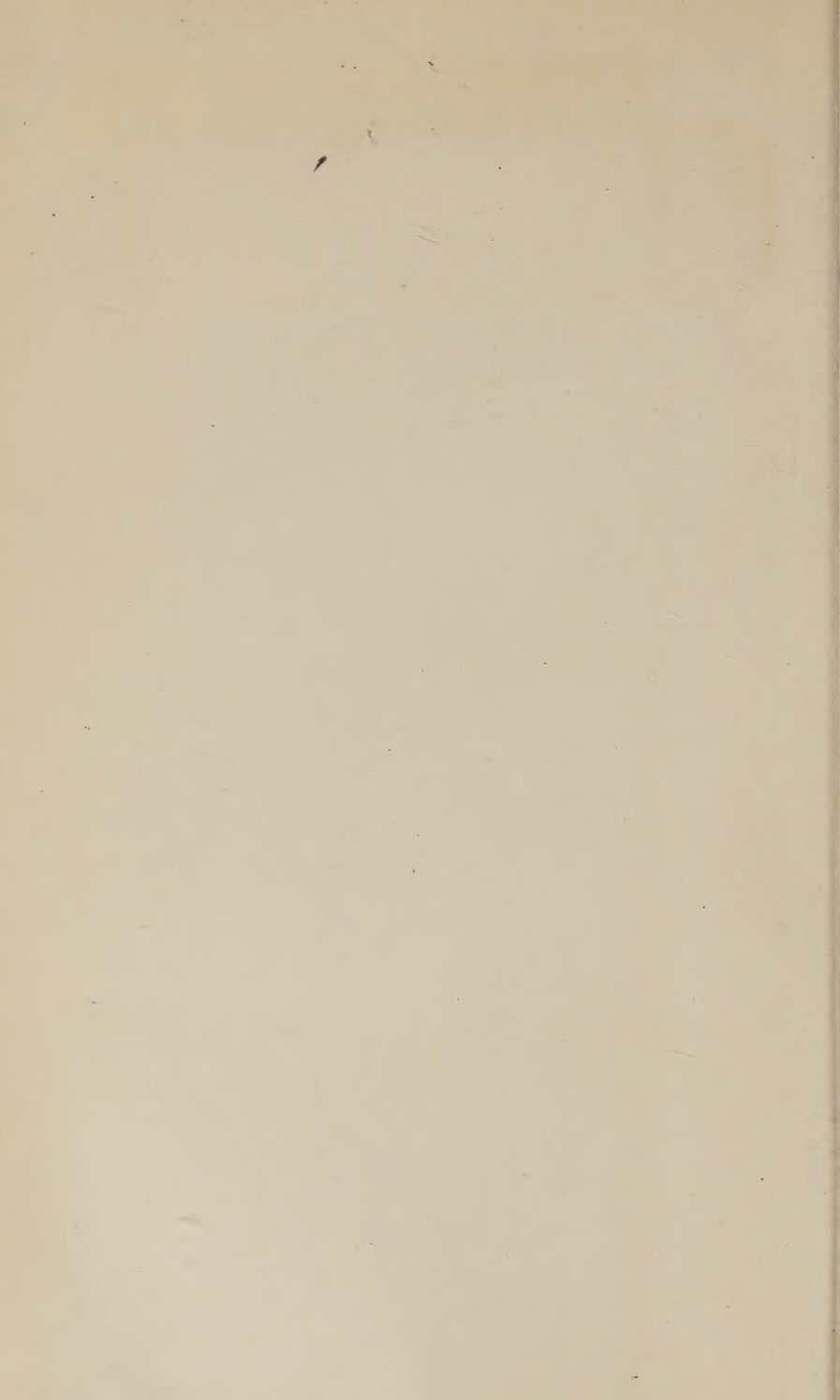
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